TEACHER'S EDITION

INTERACTION OF EARTH & TIME

SECOND EXPERIMENTAL EDITION

IET

INTERACTION SCIENCE CURRICULUM PROJECT

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RAND McNALLY & COMPANY

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PREFACE TO THE STUDENT

Earth is a planet--one of many which, together with the sun, the stars, and the emptiness of space, makes up the universe. In this course you are asked to think about a number of questions concerning the earth, including:

1. How is it possible to learn about the relationship of the earth to the sun, to other planets and to objects far out in space?

2. What lies in the depths of the oceans, and why are people interested in learning more about them?

3. What measurements must be made to know what part of the planet earth you live on?

4. How can a knowledge of the earth's surface--the forms it takes and the rocks which compose it--make life more interesting?

5. How can life be preserved on an earth which is rapidly becoming so over-populated and polluted?

6. What forces are responsible for different weather patterns around our planet?

7. Why are the highest mountain ranges found in the western part of North America instead of the eastern part?

8. What happened to the dinosaurs and other extinct life forms, and what creatures have taken their places?

9. What is the nature of the earth deep below its surface?

Perhaps these questions would not have been asked a few hundred years ago. Why, then, has the passage of time--a short time--brought about a need to ask these questions?

<u>Interaction of Earth and Time</u>, a course in earth science, is designed to prepare you to search for answers to these and other important questions.

You probably have many questions of your own to ask, and rightly so. One question you may wish to ask, is, "What do objects which are deep in space or far beneath the surface of the earth have to do with me?"

There is no simple answer to such a question at this time. But as you progress through the course you may find some partial answers.

Many of the problems we face today result from what man has done and is doing to the earth. Perhaps a knowledge of earth science will help in solving some of these problems. Perhaps it will help prevent the people of your generation from making avoidable errors.

Earth science is such a broad subject that you may sometimes find it difficult to see why one particular subject is important to the entire picture. If you do, try patience, enjoy what you do in the laboratory and read with interest; later the pieces of what may seem like a puzzle will begin to fit a pattern--the change of earth through time.

PREFACE TO THE TEACHER

Interaction of Earth and Time (IET) is the third in a series of junior high school science programs produced by the Interaction Science Curriculum Project. All materials in this edition are experimental and are made available for classroom use only to you who are actively participating in testing the program and who have attended a briefing session to acquaint you with the philosophy and methods underlying the course.

It is the authors' belief that no matter how appropriate we may think the materials are for junior high school students, the real test is their degree of success in the classroom. Future editions of IET will be based upon feedback received from teachers using the experimental editions. Our testing program for the 1970-71 school year included approximately 90 teachers and 5,500 students in the United States and Canada, in all kinds of school situations.

In addition to providing a basic course in Earth Science, IET is also designed to be used in conjunction with the physical science program, Interaction of Matter and Energy, and the life science program, Interaction of Man and the Biosphere, now available in commercial editions from the publisher.

PHILOSOPHY AND RATIONALE

Interaction of Earth and Time is a course in Earth Science based upon an inquiry system of teaching and learning. This system includes observation, investigation, interpretation, research in appropriate literature, and critical study of conclusions. We believe that repeated use of these skills should lead students to an understanding of the processes of science, as well as enable them to acquire knowledge in the earth sciences. To accomplish these goals we cannot attempt to cover all areas of related content. We consider it more important for students to explore a relataively few topics in depth.

In texts as well as in teaching, premature explanations of phenomena or disclosure of answers to problems may deprive students of the opportunity to test their abilities. Such practices tend to produce passive acceptors of fact instead of active searchers for knowledge. Most IET investigations and activities are so structured that the teacher may guide students toward achieving maximum understanding through independent discovery. Textual material is included to provide background for the laboratory activities rather than to offer answers to investigations. In some instances more specific information is given so that students will have a reasonable basis for pursuing investigations. The authors realize that only a very small percentage of students studying science in junior high school will ultimately become scientists. However, the main themes of this book are quite clearly important to all citizens of Earth.

In preparing IET, the authors proceeded on these premises: (1) Textual material and laboratory investigations should not be treated as separate entities. (2) An inquiry approach to the teaching of science is essential if students are to develop initiative and investigative skills. (3) Students must enjoy studying science. If they "tune out the teacher" and do not

become involved in the program, then they will have gained little or nothing. (4) Most students in junior high school are curious and eager to learn when they begin a new course. They will learn if they are given an opportunity to realize that a search for knowledge can be personally gratifying. (5) Students must realize that science is a search for knowledge based upon the best available information obtained through observation, experimentation, and reading, rather than upon passive acceptance of what someone else calls a fact. (6) In science, as in any other field of intellectual endeavor, students must be allowed to explore with freedom those subject areas they do not understand.

Equipment and Supplies

The materials in this book are oriented toward involvement through laboratory work and other kinds of activity. Most of the investigations call for inexpensive and reasonably simple equipment. **A complete list of materials and equipment needed to implement the investigations in this volume is provided in Appendix E.**

The Teacher's Edition

The Teacher's Edition of IET contains all of the Student Text as well as guide material for teachers. The margin of each page intended for the teacher is marked with a dark band. In all cases, such pages are inserted immediately following the relevant student material. We urge that you read well ahead in the Teacher's Edition before asking the students to carry out laboratory investigations. Whenever possible you should actually perform the procedures yourself before class time.

This will enable you to become familiar with the materials students will manipulate, to be better able to anticipate difficulties students may have, and to be able to adapt your presentation to any differences in specific items of equipment being used. Some of the Optional Investigations are not included in the student's material. In this way we have provided flexibility. Each teacher can use more or less of the additional material according to the capabilities of the class or of individuals.

The Teacher's Edition contains summaries, in the previews and in material accompanying most selections, designed to keep the teacher aware of the overall development of the section and the objectives of each investigation within that section. Since students' abilities to see general structure vary greatly, each teacher must determine how well each of his classes is aware of the larger picture. At intervals you may wish to conduct discussions based on questions such as, "What do you think the purpose of this investigation was?" "How did this investigation relate to the one before it?" etc. By judicious use of such techniques you should attempt to keep your students properly aware of the development of each section. Students who know that the purpose and "right answers" will be given to them immediately following each assignment have no incentive to seek the best answers for themselves. On the other hand, students who become bewildered and suffer from frustration are likely to give up. Only you can judge the levels of curiosity and frustration in your classes. For this reason, inquiry oriented courses depend more heavily upon the skill of the individual teacher than do conventional approaches.

Organization

This course could be thought of as a collection of separate sections--each section dealing with a different aspect of earth science. The sections have necessarily been arranged in one sequence, but others are equally reasonable and may be superior as a result of local weather conditions, student interest, correlation to subjects being taught in other courses, etc. You may wish to change the sequence to suit your own particular situation. However, in general, most teachers find it advisable to follow the printed sequence during the first year. After trying a new course for a year, they gain insight and experience that may suggest modifications. They also become aware of built-in cross references between sections and are able to anticipate these. Certain sections presuppose that students will have developed skills or acquired knowledge from previous parts of the course. The teacher who is familiar with the entire structure of the course is better able to know when rescheduling is advisable, what topics may be deleted, and which should be supplemented. However, some deviation from the established order--even in the first year--is recommended with regard to activities involving outdoor work. During the first experimental year it was discovered that student response to night observations varied greatly. Generally, in areas in which good viewing conditions prevailed students found the assignments interesting, whereas in those areas with cloudy skies and city lights the investigations were frustrating. As a consequence, most investigations involving observation of the night-time sky have been relocated in Appendix D.

Themes

<u>Interaction of Earth and Time</u> is woven about nine central themes:

1. Experimental design, observation and interpretation are best learned from personal experience.

2. Scientific models are conceptual, not physical, and are useful in organizing information, establishing relationships, and making predictions.

3. Change is the rule, not the exception.

4. Time and space are vast.

5. Many spatial relationships on earth and in the solar system can be established from simple observations.

6. Processes affecting the atmosphere, hydrosphere and the solid surface of the earth are interrelated.

7. The interior of the earth has structure, and processes are continuously altering this structure.

8. In earth science man is not the protagonist. Processes affecting the earth would not be substantially altered if man did not exist.

9. Man's activities result in changes that affect him adversely when he is ignorant of natural processes or fails to consider known processes.

These themes are not stated directly in the student text nor is it intended that the teacher should state them for him. It would be an easy matter for students to memorize, for example, "Time is vast" and repeat it unerringly in tests without ever developing a feeling for the awesome depths of geologic time. It is hoped, instead, that subtle guidance by text and teacher will lead the student to an awareness of these themes whether or not he can state them in words.

We request that you refer back to them occasionally in order to help in determining whether the course is accomplishing what it was intended for.

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SECTION TEN: SEEKING LARGER PATTERNS

SECTION ELEVEN: EARTH, SEA AND AIR

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Section One:

Developing Tools

PREVIEW

The introductory reading material and Investigation 1.1 may serve as the basis for class discussions of the scope and nature of earth science. Investigation 1.1 also provides a background in experience for the subsequent reading selection, "Models." It is not anticipated that students will fully comprehend the potentialities of scientific models at this time. A better understanding should develop in the course of the school year.

Text and laboratory materials dealing with angles, azimuths and compasses are included to provide skills students will need early in the course. (Other aspects of measurement are considered in Section Five.) If your students are already familiar with protractors and their use, the material may be treated lightly. In any event, do not spend much time or place too much emphasis on the material.

The section closes with "Where Are You?", a selection designed to make students aware of the problem which is to be worked out in succeeding sections.

IMPORTANT: THE SCHEDULING OF INVESTIGATION 2.1 IS CRITICAL AND MAY PRESENT DIFFICULTIES IF NOT CONSIDERED BEFOREHAND. PLEASE GLANCE AT THAT INVESTIGATION AND THEN READ THE FOLLOWING COMMENTS WITHOUT DELAY.

Investigation 2.1 calls for outdoor observation of the sun by means of a gnomon. Although Investigation 2.1 and 2.2 should ideally be done on consecutive days, the lapse of several days between the two will not be detrimental. Obviously, the outdoor work should be done on a clear day. If in your area clear weather is not dependable during the first weeks of school you should start the course with Section One but interrupt the sequence ON THE FIRST CLEAR DAY in order to have your students obtain the gnomon record called for in Investigation 2.1. You may then return to Section One, retaining the gnomon records till needed (Investigation 2.2). Or once 2.1 is completed you could follow with 2.2, postponing the rest of Section One until the need for techniques perfected there becomes apparent. If you worked through all of the material in Section One and then encountered a week of inclement weather you could become stalled, since it is not possible to skip over 2.1 without loss of effect.

Section One:

Developing Tools

Parts of this book are labeled as "investigations." You may wish to think of investigations as being similar to experiments. Experiments, though, must be done in a very exact form in order to be true experiments. The authors feel that much of the information which will be interesting to you can be gained without the formality of a true experiment. Therefore we prefer to use the term investigation. You will notice that not all the investigations are similar in the ways in which you are asked to approach problems.

In the investigations you will find procedures, interpretations, and (in some cases) problems. Procedures describe things for you and your teammates to do. As you perform the procedures you should observe what is happening. You may wish to make notes of what you see. In some cases you will be asked to write or draw descriptions of things that are happening.

Following some of the procedures will be interpretations. Interpretations will generally require that you think and write about what you have done. Since the laboratory investigations have been set up in a step-by-step sequence, you should

try to think out your interpretations at the time they are called for. In other words, do not do all the procedures in an investigation first and then try to interpret what you saw. In some cases thinking out one interpretation will help you know what to look for as you perform the next procedure.

The two steps, observing and thinking, are what lead scientists to conclusions. Not everyone in your class, or in your team, will see exactly the same things happen. Different observers will interpret observations in different ways. Thus you and your classmates--like investigators the world over--may come to different conclusions.

From time to time you should compare your conclusions with those of other students. The purpose of comparison should not be to make certain that everyone has the same answer. Instead, comparison should serve to show how different investigators can arrive at different opinions.

Whenever you are tempted to change your mind to agree with the majority remember this: Every great scientific discovery in history has resulted from one of two situations. The scientist making the discovery saw something others had missed, or he interpreted observations in a different way from everyone before him.

TEACHER
MATERIAL

In the true sense of the word, an experiment is an investigation in which two or more "runs" are made with nearly identical materials and procedures. One run is considered a control. Other runs are made in which only one element of the materials or procedures is changed. Thus any difference in end result may be attributed only to the changed element.

An experiment is set up in order to test a hypothesis. Possible results of the experiment will indicate that the hypothesis is valid or that it is not. Which of these conclusions is to be drawn should follow directly from observation of the experimental procedures.

Although investigations may follow structured experimental format, they may also take other, less rigid forms. Strictly speaking, one cannot experiment with volcanic eruptions or with stars or with earthquakes. He can only observe and interpret. Thus, many of the phenomena of earth science are not susceptible to experimentation, and the more general term, investigation, is preferable.

How much you will wish your students to deviate from the written procedures will vary from class to class. Some students may have to be encouraged to think up variations on the investigations. Others may have to be inhibited. Generally speaking, the more variation the better within the limits of safety. Being familiar with topics to be covered in future investigations will enable you to decide whether extensions or variations of investigations which students propose can best be dealt with immediately or postponed until they are more appropriate.

The willingness of students to adhere to their own conclusions in the face of opposition can be encouraged by you in discussion and by the way in which tests are designed.

INVESTIGATION 1.1: Describing Objects

In this investigation you will study a rock, one of the things of which the earth is made. You will also look at two manufactured objects. Their relationship to the earth may not be apparent. In studying these objects you may learn something about each of them. You may also learn something about the way in which a scientist works.

Materials

Disc
Paper clip
Rock
Thread
Ruler
Tape

Procedures

A. Examine the disc. Write a description of it in your notebook. Tell what you think the disc might be used for.

B. Place the disc and the paper clip close together. Describe any interactions you observe. By this it is meant that you should try to see whether the objects act upon each other in any particular way.

C. Tie a piece of thread about 15cm (6 in.) long to the disc. Tape the other end of the thread to the edge of your work table in such a way that the disc is suspended over the edge. Describe the behavior of the suspended disc.

D. Examine and describe the rock. Next suspend it from a piece of thread so that it is hanging at the same height as the disc and about 15cm away from it. Describe any unusual behavior of the two suspended objects. Then remove the disc and observe the rock.

Interpretations

1. How do you account for any interactions between the rock and the disc that you may have noticed?

2. What properties, if any, of the rock could not be told simply by looking at it and handling it?

3. What uses, if any, do you think this type of rock might have?

TEACHER
MATERIAL

INVESTIGATION 1.1: Describing Objects

This investigation allows students to become familiar with the format of the investigations which will be a major feature of the course. From it they should learn to distinguish between observations and interpretations.

The investigation also provides a background for discussions concerning earth science and concerning the scientific thought process.

Try to avoid mentioning the name "lodestone" until after the investigation. The name might provide some students with clues to the nature of the rock, something they should be permitted to discover (or fail to discover) on their own.

Similarly, distribute the "discs" (ceramic magnets) and paper clips in a way that will allow each team of students to discover the properties for themselves.

Materials

There should be one ceramic magnet and one lodestone per team.

Test the paper clips beforehand to be sure that they are attracted by the magnet.

One spool of thread may be shared by the class, and one or two rolls of tape should be sufficient.

Procedures

A. It is recommended that you walk around the class passing out one "disc" per team. Allowing students to pick them up from a group of magnets together on

a supply table might exhibit their magnetic properties in a fashion which is too obvious. Students should note color, size, shape and approximate weight of the disc. Speculation on possible uses of the disc should be encouraged.

B. The disc and paper clip will be mutually attracted.

C. The disc will tend to orient itself with one of the flat sides facing north. See Figure T-1.1.

Figure T-1.1.

Many students are surprised to find that poles of the magnets correspond to the faces rather than the edges.

D. Again, it is recommended that you pass out the rocks in order to avoid premature disclosure of their magnetic nature. Some students may think to test the rock for magnetic properties. Others probably will not.

When suspended near each other the rock and disc "dance" about in an unpredictable fashion. When the rock is suspended by itself it will tend to twirl slowly for a period of time, then oscillate back and forth, and finally settle into alignment with the earth's magnetic field. Again, some students will probably notice the rock's tendency to align itself, and others will not.

Interpretations

Some teachers prefer to have each student interpret his results before a class discussion. Others will want to encourage discussion while observations are still fresh and interest may be higher. The choice is yours. In a discussion try to encourage a variety of responses and avoid tagging some correct and others incorrect. When differences of opinion arise, invite students to suggest whether the difference arises from variations in observations or differences in interpretation or a combination of the two.

1. Most students should suggest, correctly, that the attraction was that of a magnet (the disc) for an iron object (the paper clip).

2. The magnetic properties of the rock could not be observed until it was brought close to an iron object.

3. Lodestone is useful as an iron ore.

It is possible that the paper clip was smelted and manufactured from an ore similar to the lodestone. This might suggest the economic possibilities of a study of earth science. You might ask students to name useful items which have been obtained from the earth. More difficult would be a search for items <u>not</u> directly or indirectly obtained from the earth. Wood products, for example, are obtained from trees which in turn depend upon the soil in which they grow.

Students who observed that the rock was magnetic, and not passive as was the paper clip, may suggest that a piece of lodestone might serve as a compass. The first compasses were, indeed, lodestones. The tendency of compasses and lodestones to align themselves suggests an important property of the earth, its magnetic field. Students might wish to speculate on whether magnetic compasses could be used in space or on other planets.

MODELS

It is not easy to tell a person <u>what</u> to think. Each person is an individual and likes to think his own thoughts. It is even more difficult to tell a person <u>how</u> to think. Thought processes are hard to describe. One major purpose of this course, though, is to describe to you one system of thinking. This system has been helpful to many people, and it may be helpful to you. It involves something known as a "model." Our definition for "model" is "A useful way of thinking."

At times in the course you will be asked specifically to think in terms of models. At other times you may find it helpful to think in terms of models even though you are not asked directly to do so.

Perhaps the best way for you to learn how models can be used is to use models in describing something you have done. In Investigation 1.1 you studied three objects. You may have reached some conclusions about their natures. Imagine the following conversation between two students as they work on Investigation 1.1. Keep in mind that theirs is not the only way to have thought about the problems. Neither is it necessarily the right way.

A: What did you put down for a description of the disc?

B: I said it was a dark color, about an inch square and one-quarter inch thick, and had a hole in it.

A: Same here. I also said it weighed a lot less than a pound, maybe an ounce. What do we do next?

B: "Place the disc and paper clip close together." I'll try it. Hey, what do you know?

A: I guess that disc is a magnet of some sort.

(Student A has just suggested a <u>model</u>. In other words, it is possible to understand what has occurred if you think of the disc as being a magnet.)

B: It seems pretty light for a magnet. All the magnets I've ever seen were heavy, like iron. Do you suppose the paper clip could be the magnet?

(Now Student B has suggested a different model, another way of thinking which might explain the interaction of the two objects.)

A: Easy enough to find out. See, the disc attracts the wire ring in my notebook but the paper clip doesn't.

(This is good scientific procedure. When two models have been suggested a test of some sort is needed to find out which model is better.)

B: Look what happens when you hang the disc from a thread. It always wants to face one way--like a compass.

(Another observation has been made which supports the "magnet model.")

A: How about this for a description of the rock: "Dark colored and heavy, even for a rock."

B: O.K. Better put down that it's shiny, too. Like it had iron in it.

(This thought can also be thought of as a model: the heavy, shiny nature of the rock would be possible to understand if the rock contained iron.)

A: Let's check that out. Hold it next to the disc.

(Again, this is good procedure. The strength of a model depends upon the number of tests it can pass.)

B: Look at that. The disc is pulling toward it. The rock has iron in it.

A: Write it down. I guess we figured that one out.

(This is risky. The test with the magnet supported the "iron in the rock" model. But that does not mean that the model is the <u>only</u> model. Nor does it mean that the "iron in the rock" model cannot be improved.)

A: When the rock and disc are hanging side-by-side they sort of dance around.

B: The magnetic disc tries to pull them together, but their weight keeps pulling them apart.

A: Now we're supposed to take away the disc and watch the rock by itself. Anything?

B: Nothing. It just spins around.

QUESTIONS FOR DISCUSSION

1. The students have accepted a model which explains all their observations about the disc and the rock: The disc is a magnet and the rock contains iron. Can this model be improved upon or replaced with a different model?

2. How could other models for the rock and the disc be tested?

3. Do you think that students A and B interpreted their observations in a reasonable way?

4. Do you think that the students made accurate observations?

TEACHER MATERIAL

MODELS

It is unfortunate, perhaps, that the word "model" is used to describe the scientific thought process instead of some other word. There is a tendency to confuse scientific models with small-scale physical replicas, such as "model airplanes." In this course the term is used consistently to refer to the scientific thought process, and never to a physical representation. Although definitions for the term model may vary somewhat, the sense in which it is used in this course is consistent with contemporary scientific usage.

Some discussion of scientific models is in order at this point, but it would be unrealistic to hope for a true understanding of the concept before the students have worked with various models dealing with the solar system, etc.

QUESTIONS FOR DISCUSSION

1. Answers will vary. The model is satisfactory in that it explains what was apparently A and B's only observation: that the disc and rock attracted each other. The model has shortcomings which become apparent if other observations are made.

2. Some members of your class may have noticed that a particular face (pole) of the ceramic magnet would attract some parts of the lodestone but not others. This suggests a different model, that the lodestone is composed of (or contains) <u>magnetized</u> iron. Other members of the class may have noticed the tendency of the lodestone to attract the paper clip, or its tendency to seek a particular orientation when suspended. These observations would also favor thinking of the rock as being a magnet itself.

3. Student A and Student B interpreted their observation (that the rock was attracted to the disc) in a reasonable way.

4. Student A and Student B were apparently not sufficiently careful in their observations to see everything which they might have.

INQUIRY DEMONSTRATION: Magnets and Models (Optional)

If student interest in the foregoing topics is high you may wish to conduct an inquiry demonstration along the following lines.

Preparation

Obtain a small horseshoe magnet from a toy store. Stroke a paper clip with the magnet a hundred or more times. Always use the same pole of the magnet and always stroke in the same direction, not back and forth. The paper clip should now be magnetized.

Hold the horseshoe magnet in the flame of a bunsen burner with pliers until the magnet reaches a red stage. Allow it to cool. The horseshoe will now be demagnetized.

Attach the paper clip to the horseshoe "magnet" with a drop or two of glue and allow to dry.

Demonstration

(Hold the magnet up in front of the class with the paper clip suspended from it.)

Teacher: What holds the paper clip up?
Possible Response: The horseshoe thing is a magnet.

Teacher: That's a likely <u>model</u>. We can understand why the clip doesn't fall if we think of the horseshoe as being a magnet. Are any other models possible?

Possible Response: Varied

Teacher: If necessary, ask: Would the objects behave in this way if the clip is magnetic and the horseshoe is not?

Possible Response: Yes.

Teacher: How could we tell which model is better?

Possible Response: Try both out on another paper clip.

Teacher: That's right. We need to <u>test</u> the two models. Could we explain the fact that the paper clip doesn't fall by thinking that they are glued together?

Possible Response: Yes.

Teacher: How could we tell if glue is involved?

Possible Response: Look to see.

Teacher: Yes, we need more <u>observations</u> to see which model is best. (Let a student in a front-row seat look closely at the objects but not touch them.) Tell me what you see.

Possible Response: Glue!

Teacher: That observation supports the glue model. Does it necessarily mean that other models are incorrect?

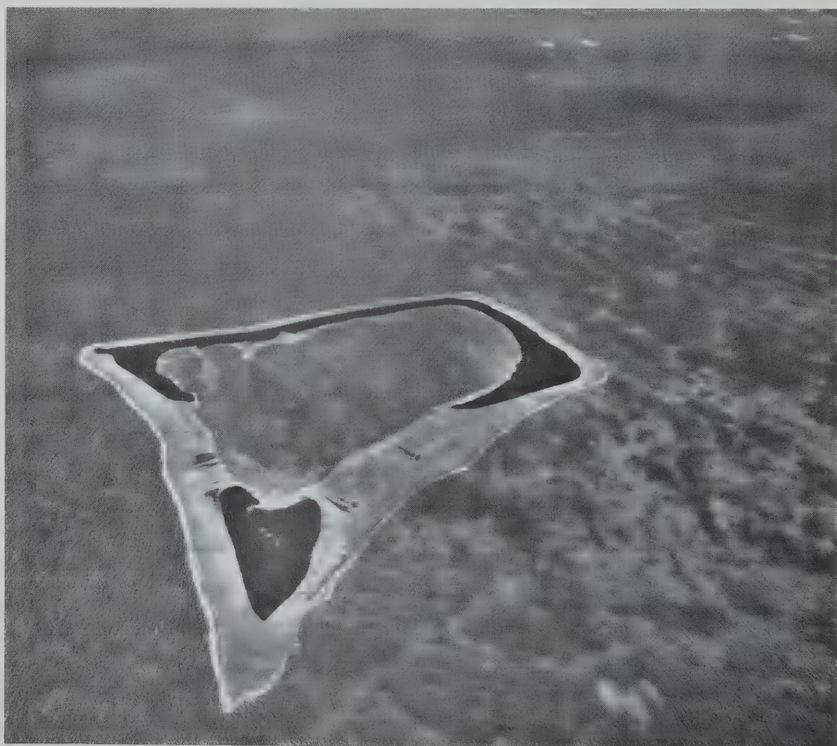
Possible Response: No. The fact that one model is useful does not mean that others cannot be.

Teacher: (Break glue bond; then demonstrate that paper clip is magnetized and horseshoe is not.) In summary: More than one model, more than one way of thinking, may be possible. If there are two or more ways of thinking some more tests and/or observations should be made. The fact that one model is "right" does not mean that others must be "wrong."

WHERE ARE YOU?

Among the several questions asked in the preface to the student was, "What measurements must be made to know what part of the planet earth you líve on?" At first glance this may seem like a simple question. But is it?

Figure 1.1. Where are you?



"Imagine yourself shipwrecked on a tiny uncharted island somewhere in the Pacific Ocean." Since "Robinson Crusoe," this idea has been the basis for many exciting and enjoyable stories. Many even dream of such a fate as a good way to get away from the rush, crowds, and problems of our time. (In truth, however, most small islands will not support human life, because they lack food and fresh water.)

But suppose you are in such a situation. You have managed to save a battery-powered two-way radio, a magnetic compass, and a protractor along with some food and water. After a short time, you make contact with a distant radio operator. After you describe what has happened he asks, "Where are you?" How would you answer? How would you be able to give useful information for a search party to follow?

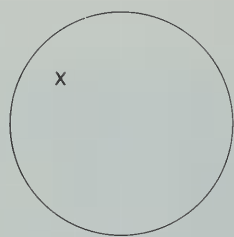
Now stop and think for a moment about where you are today. What would you have to do to tell your exact location to someone in a distant country who wants to visit you but is not familiar with your part of the world? You already have half the problem solved because <u>you</u> know where you are. Now all you have to do is tell your visitor how to get here. Make a list of the kinds of information your directions must include.

If you live in a small town, your description of location might include a reference to some large city nearby, such as, "I am about 35 miles northwest of Denver," or "I live 70 miles south of Chicago." If you live in a large city, you might include references to some large building or famous landmark. Most descriptions of location must include three things: <u>Direction</u>, <u>distance</u>, and the relationship of these to some <u>known reference point</u> or points. If you are familiar with your area, you can probably give your location fairly accurately.

Now put yourself back on that lonely island. Even if you are lost somewhere in the Pacific Ocean, determining your location involves finding the same information--direction, distance, and a reference point or points.

Study Figure 1.2. Let the mark (X) represent your island. Discuss with your teacher how you could determine the location of the mark on the globe. Your discussion should include ways to establish direction, distance and reference point(s).

Figure 1.2.



PROBLEM

When you think you know how to describe locations, place a dot on a globe. Describe the location of the dot to the members of another team. Do not look at their globe or allow them to look at yours. Were you able to tell the other team where the dot was located? Did you make use of reference points, distance, direction?

TEACHER MATERIAL

WHERE ARE YOU?

The reading material is intended to focus student attention on the problem of locating oneself on the earth. Appealing to a higher authority such as a map is, of course, one way students may suggest to establish location.

The authors believe that a more rewarding procedure is to have students find out how to establish location through individual effort. In doing this they should understand that reference points and directions are necessary to any method of locating points on Earth.

It would probably be best to divide the class into teams of three or four students each. It is recommended that each of your investigation teams have a globe to be marked and used during discussion.

PROBLEM

Students will probably find it impossible to describe the location of the dot. One student may suggest that the dot is above, or north of, the equator on his globe, while another may insist that it is below the equator. References to directions such as north or west are meaningless on the unmarked globe.

Discussing how to describe the position of the dot should bring out the need for ways to determine directions and to establish more than one reference point on such a globe. Furthermore, students should come to see that a universal locating system must be based on a widely accepted and convenient set of reference points and directions.

Investigation 1.2 allows students to establish a reference direction by use of a magnetic compass. As students continue the investigations in Sections Two and Three, they will discover how to use the sun and stars in establishing a reference system. But to do this it will be necessary to know something about earth-sun and earth-star relationships. In the following investigations, students will be given the opportunity to build a model for these relationships. The teacher should therefore refrain from describing a solar system model at this time.

ABOUT ANGLES AND DIRECTIONS

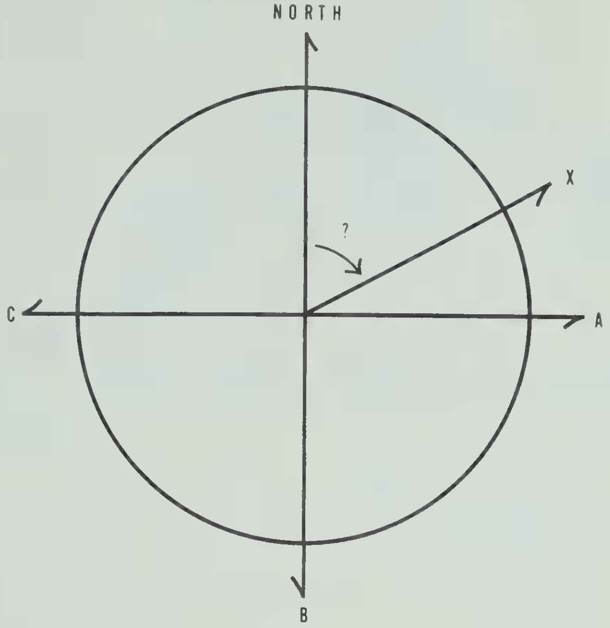


Figure 1.3.

Imagine yourself standing in the center of a large circle like the one shown above. If someone asked you what direction arrow "A" is pointing you could easily give the correct answer--east. But what if he asked for the direction of arrow "X"? How would you answer if asked to give the difference in direction between the north arrow and arrow "X"?

To answer these two questions you must first learn about angles and how they are measured.

An angle is formed when any two lines are drawn out in different directions from a single point. The most common way to express angles is in units called degrees. One degree (1°) is a very small angle and describes a small difference in direction. Two lines that are drawn in exactly opposite directions from a point form a 180° angle. At each corner of this page, the angle formed by the edges of the paper is 90°. If you stood in the center of the circle facing north and turned all the way around until you faced north again you would have turned through 360°.

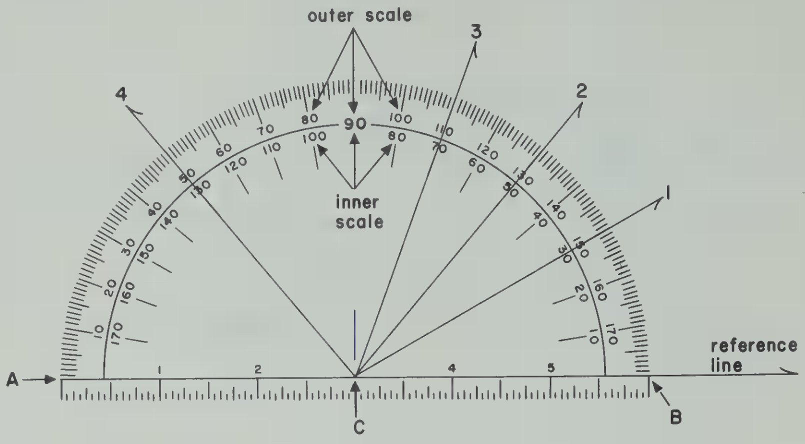


Figure 1.4.

A protractor (Figure 1.4) is marked in degrees and can be used to measure angles.

Before measuring an angle with a protractor you must first select one of the two lines forming the angle as a reference line. In Figure 1.4 four angles are formed with the reference line.

To measure an angle with a protractor, place the center (C) at the point where the two lines meet. Move the protractor so that a zero degree mark (A or B) is on the reference line. If A is placed on the reference line, use the outer scale to read the number of degrees at the point where the second line crosses the scale. This is the number of degrees in the angle. If B is placed on the reference line, use the inner scale to read the number of degrees in the angle. What is the measure of each of the four angles shown?

INVESTIGATION 1.2: Determining Angles and Direction

In this investigation you will practice measuring angles with a protractor. You can then use another instrument, the magnetic compass, to determine direction.

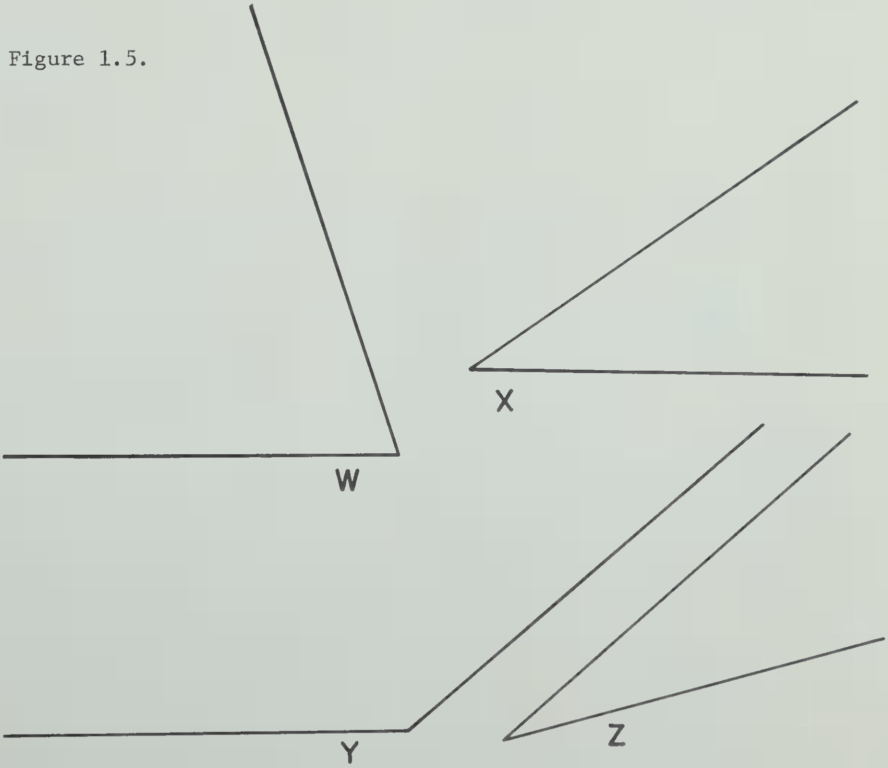
Materials

Ruler
Protractor
Magnetic compass

Procedures

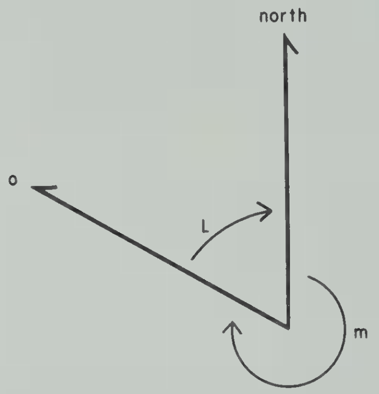
A. Measure and record in your notebook the number of degrees in each of the following angles.

Figure 1.5.



B. The two lines below (Figure 1.6) are shown to form two angles. (Actually, any two lines drawn from a point form two angles, not just one.) Devise a method to measure both angles shown. Record your answers in your notebook. Hint: A complete circle contains 360°.

Figure 1.6.



C. Degrees are also used to describe directions on earth. Hold the magnetic compass so the needle is free to swing. The needle is made of magnetized metal and will point north if no nearby metal objects attract it. Magnetic compass directions are often described as <u>azimuths</u>, and are expressed in degrees. The reference direction is north, and the angles are numbered clockwise in a circle (angle M, Figure 1.6).

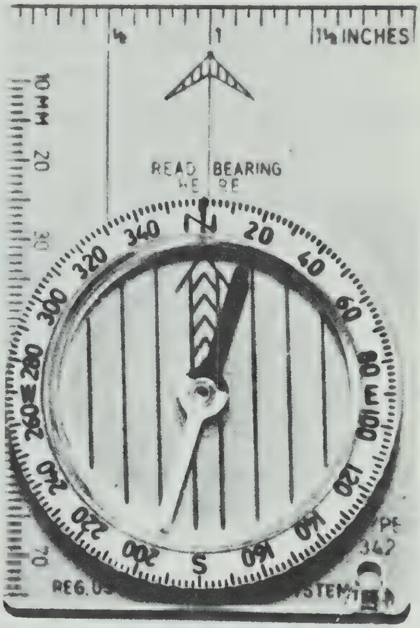


Figure 1.7.

A magnetic compass.
Note that a 360-degree circular number line is drawn around the compass, beginning with zero degrees (0°) at north.

PROBLEMS

1. What is the azimuth of east?

2. Use the compass to find the azimuth (degrees from north) to the teacher's desk from your location.

3. In what direction does the hallway outside your classroom run?

TEACHER MATERIAL

INVESTIGATION 1.2: Determining Angles and Directions

This investigation and the text preceeding it are intended to develop some of the skills students will need in later investigations and to help answer the question, "Where are you?"

Materials

Compasses should be calibrated in degrees of azimuth.

Procedures

A. Angle W = 72°
X = 36°
Y = 140°
Z = 26°

B. Angle L = 60°
M = 300°

PROBLEMS

1. The azimuth of east = 90°; south = 180°; west = 270°.

2. Answers will vary.

3. Answers will vary.

Section Two:

Gathering Evidence

PREVIEW

The section begins with an Inquiry Demonstration which defines directions on a globe and illustrates the necessary direction of rotation of the globe.

The first investigation of the section, 2.1, involves students in using a gnomon to obtain a record of the sun's apparent path across the sky in the course of a day. This is followed by an analysis of the investigation in which it is found that apparent solar noon and clock noon do not coincide. The true north direction is also found and compass declination measured.

In a reading selection students are introduced to the problems involved in defining such terms as "up" and "horizontal" for observers located at different points on a globe.

Students then use globes and "indoor" gnomons to observe the similarities between the records they obtained of true shadow lines and those generated on the small rotating globe. Inferences can be made concerning the students' general location on the earth.

The model of the earth-sun relationship is adjusted to fit the observed changes in lengths of daylight periods at different seasons of the year. This is accomplished by tilting the rotational axis of the globes.

The change in the model is referred back to check it against the behavior of indoor gnomons, and a prediction is made: If the axis of the earth is tilted, shapes and locations of the gnomon shadow lines should change in predictable fashion.

The section closes with a suggested set of observations of the circumpolar constellations.

Throughout the section emphasis should not be so much on "What do you know about the earth-sun relationship?" but rather on the question "What observations that you can make support the concept of the earth as a globe rotating on a tilted axis?" In other words, "<u>How</u> do you know what you know?"

Note: If the investigation with the outdoor gnomon has not yet been conducted, it should be scheduled for the first clear day.

INQUIRY DEMONSTRATION: Day and Night

A globe which is rotated in front of a light source can be used to simulate sunrises and sunsets on earth.

The rotational axis of this globe provides a basis for a system of directions. Once one point on the globe has been selected to represent the north pole, all directions on the globe as well as its direction of rotation are established.

It is important that students realize that the globe and light source are not "models" in the sense that the term will be used in this course. Instead they help to illustrate the model--a way of thinking about the earth and sun.

The demonstration is intended to provoke curiosity, to establish some working definitions, and to suggest to the students how the globe and light source may be useful in future investigations.

Materials

Unmarked globe
Large beaker or wide mouth jar
Rubber suction darts (2)
File cards (2)
Marking pen
Masking tape
Light source (a slide or movie projector gives best results)

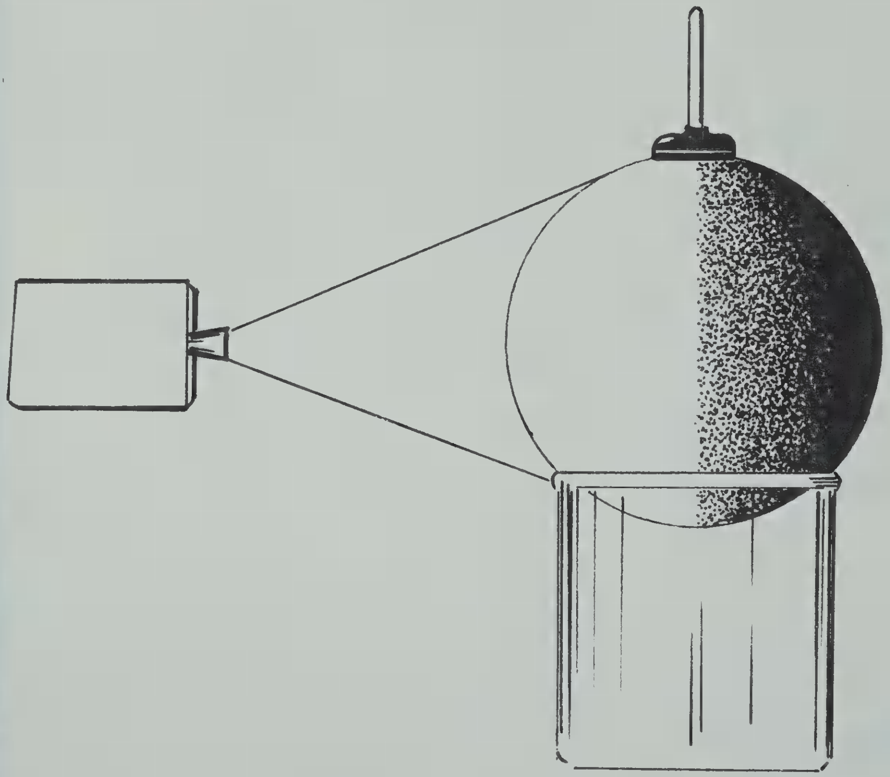
A standard geographical globe of the type often found in schools may be used, but it is felt that an unmarked sphere (such as a basketball) is better. The standard globe will already be marked with poles, equator and other reference features. It is the purpose of this demonstration to show how these references are established. Their prior presence on the globe may detract from this purpose.

It is unlikely that your demonstration and the accompanying discussion will follow the exact outline suggested here, nor is it necessary. Use your own imagination and "play it by ear." Do attempt, however, to cover the major ideas suggested and avoid <u>telling</u> students answers which are covered later in the section.

If possible, take time to scan the ideas in the Teacher Material for the next several investigations just before your demonstration. This will help you to avoid disclosing information which students can discover for themselves in those investigations.

Preparation

Before class set the globe up in front of the class and place the light source off to one side. Check to see that the light source produces a fairly distinct day-night line which is visible from all parts of the classroom. The light source should be at the same height as the center of the globe. Figure T-2.1.



To the student: "You should recall the problem of locating a point on an unmarked globe. How could we establish a system of direction on this globe? For instance, let's start with north. Where shall we locate the "north pole" on the globe?"

Student response: (On the top.)

To the student: "All right, I'll put this suction dart at the top of the globe to represent the north pole. Then where does the "south pole" *have* to go?"

Student response: (At the bottom.)

If you feel that students may not be aware of the meanings of the terms "north pole" and "south pole," point out that the earth seems to rotate. The line around which the earth rotates is known as its *axis*, and the imaginary intersections of this axis with the surface of the earth are known as the north and south poles.

To the student: "Notice that once we've decided where the *north* pole dart should go, there's no choice any longer. The south pole dart has to go right opposite. Why is that? Why can't we put the north pole at the top and the south pole over on one side?"

Student response: (Because it isn't really that way. Because the axis goes straight through the earth. Because south is directly opposite from north.)

To the student: "What is meant by the direction *north*?"

Student response: (Toward the north pole.)

To the student: "Notice that two people who were both traveling north, but from opposite sides of the earth might be traveling toward each other. How is that possible?"

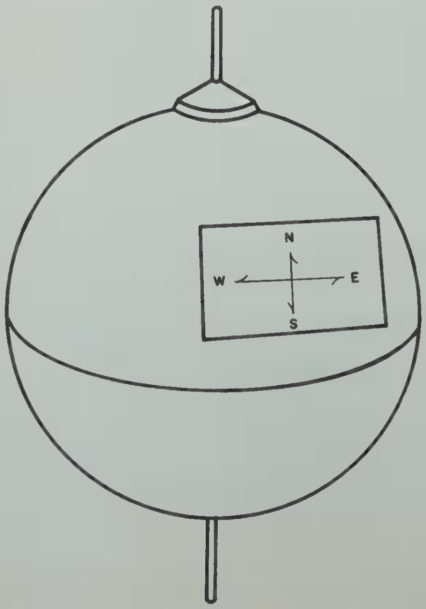
Student response: (Because wherever you are, "north" means toward that one point, the north pole.)

To the student: "Would it be possible to go completely around the world by heading north continuously?"

Student response: (No. Because once you get to the north pole you can no longer go any farther north.)

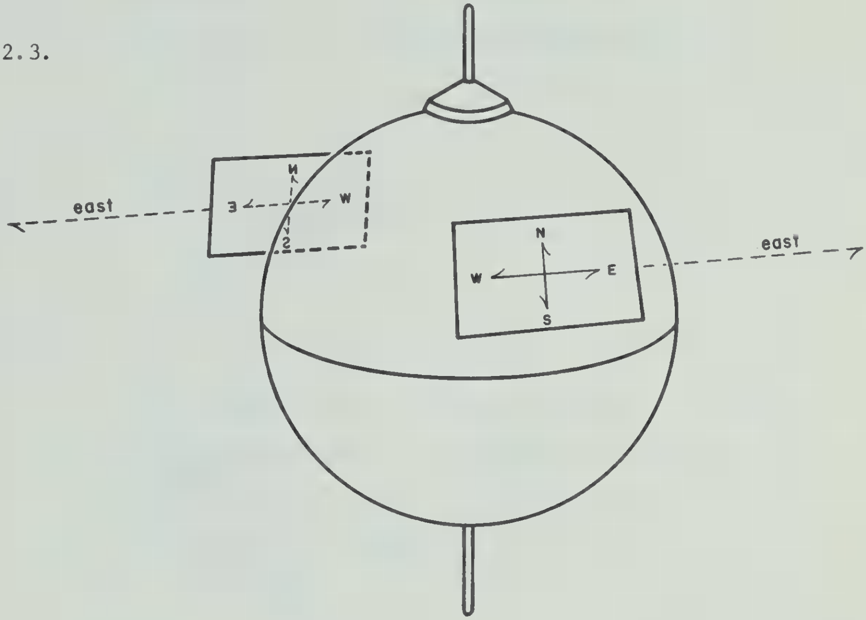
To the student:	"North is now defined. It means toward the north pole. If that is so, what is "south"?"
Student response:	(Just opposite from north. Away from north. Toward the south pole.)
To the student:	"What is meant by east?"
Student response:	(To your right when you are facing north.)
To the student:	"I'll mark north, south, east and west on this file card and stick it to the globe with tape. (Figure T-2.2.) Notice that if you were standing on this globe at the point where the card is attached, north would be toward the top of the globe, east would be on your right as you faced north, and west would be on your left. South would be behind you. What about someone on the other side of the globe? (Put a second card, marked in the same way on the opposite side.) What do you notice about "east" for the two observers?" (Turn the globe so both cards are in view.)

Figure T-2.2.



Student response: (For one observer east is toward the front of the room. For the other it is toward the rear of the room.) Figure T-2.3.

Figure T-2.3.



To the student: "Would it be possible to go completely around the world by heading east continuously?"

Student response: (Yes.)

To the student: "Would it be possible for two people, each traveling east, to meet each other head-on?"

Student response: (No.)

To the student: "Now I will turn on the light source so that half of the globe is lighted. What is the common name for the lighted half of the earth?"

Student response: (Day or daylight.)

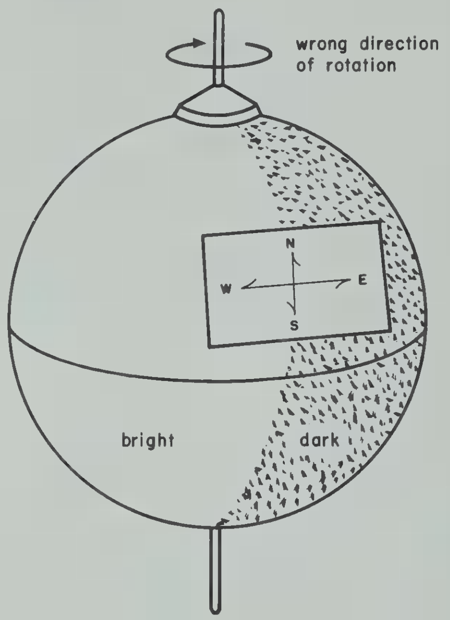
To the student: "For the dark side . . .?"

Student response: (Night.)

To the student: "Suppose I turn the globe until the observer, marked by this card, is right on the day-night line. What time is it for him?"

NOTE: Remove the observer card on the lighted side. Rotate the globe in the "wrong" direction. This is, turn it so the remaining observer is traveling toward the west. Figure T-2.4.

Figure T-2.4.



Student response: (Early morning. Evening.)

To the student: "There seem to be two answers. Let me do that again. Notice that the observer, marked by the card, is just moving from dark into daylight, so the time must be . . .?"

Student response: (Morning.)

To the student: "But notice the direction the observer would have to look in order to get his first view of the sun or sunrise, as shown by the directions on the card."

Student response: (He would have to look west. That's wrong. In the morning the sun is in the east.)

To the student: "You're right. Something is wrong, but what?"

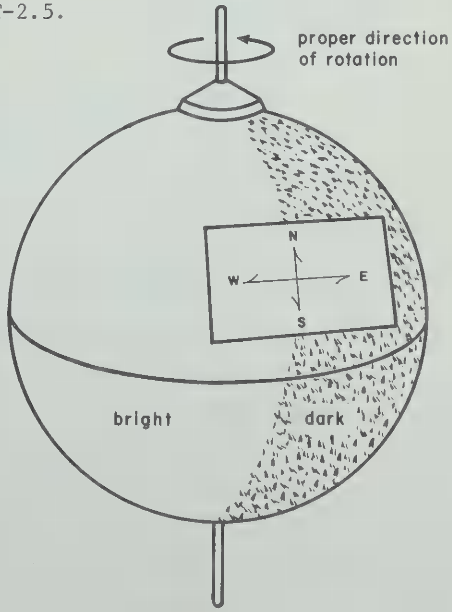
Student response: (Maybe the card is marked incorrectly. You are turning the globe in the wrong direction.)

To the student: "Two possibilities have been suggested. Let's check both. First, what about directions. When you face north is east on your right?"

Student response: (Yes.)

To the student: "Suppose I turn the globe all the way around in the other direction. (Figure T-2.5.) Now as the observer reaches the day-night line he is traveling from light into dark. At what time of day does that occur?"

Figure T-2.5.



Student response: (Evening.)

To the student: "What direction, as shown by the card, would the observer have to look in order to see the sun go down?"

Student response: (West.)

To the student: "Does that agree with what you have observed in the real world?"

Student response: (Yes.)

The following material is optional and can be done if students indicate continuing interest.

To the student: "That means that I must be careful to rotate the globe in the proper direction. Earlier we decided to have the north pole at the "top" of the globe. Suppose we wanted to call the other, bottom, end of the globe north. Would that work?"

Student response: (Yes, but you would have to rotate the globe in the opposite direction. No, because that would put us at the bottom of the globe, and we know we are at the top.)

To the student: "That second answer brings up a good point. We must be careful to say whether "up" means for us in the room or for an observer at this point on the globe. Your text will tell you something about this in the reading assignment "Up and Down." For the moment let us assume that we may put the north pole of the globe "down" (reference to the room), notice that I must rotate it in <u>this</u> direction in order to have sunrise occur in the proper direction. If you were on the equator how could you recognize the fact?"

Probable Response: This is a difficult question. Students may or may not be able to provide valid answers. On the globe as demonstrated the sun would appear to pass directly overhead. Avoid discussion of tilt in the earth's axis as this will be brought out in a later student investigation. Try to focus attention on the fact that <u>something</u> about the sun's position and path in the sky should provide clues, and this topic will be considered soon.

Summary

Summarize the demonstration and emphasize that the rotating globe and projector are not what we mean by a model. They only <u>illustrate</u> a model, or way of thinking about how the earth and sun are related. The model they have just worked out is useful because it helps us to understand why the sun rises and sets in the directions which are actually observed. Other models may be possible. It may be possible to improve this one.

Section Two:

Gathering Evidence

INVESTIGATION 2.1: The Gnomon

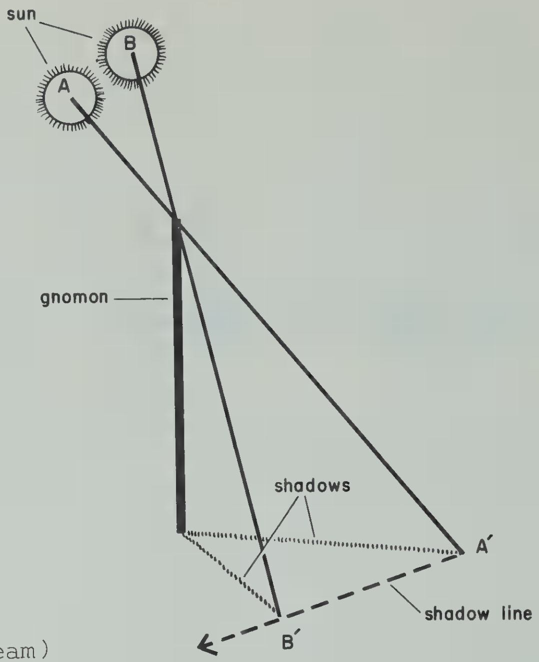
Each day the sun appears to rise, trace a path through the sky, and then set. You may have noticed that at different times of the year the path followed by the sun is different.

Astronomers of thousands of years ago made similar observations. In order to improve their observations they used a device called a gnomon (no mon). A gnomon is simply a tall, thin object which casts a shadow when the sun shines on it. An observer can keep track of the sun's position in the sky by noting the length and direction of the gnomon's shadow.

Figure 2.1 shows the principle of the gnomon. As the sun moves from position A to position B the shadow of the gnomon moves from position A' ("A-prime") to position B' ("B-prime"). The path followed by the tip of the gnomon's shadow is called a "shadow line."

In this investigation you will use a gnomon to make a record of the sun's path across the sky. In future investigations you will be asked to interpret gnomon records in order to help you understand something about the movements of the earth and the sun. Such records may also help in answering the question, "Where are you?"

Figure 2.1.



Materials (per team)

Gnomon board
Gnomon
Piece of unruled paper, 8 1/2" x 11"
Maǵnetic compass
Ruler
Masking tape
Watch or clock

Procedures

A. Carefully set your clock or watch so that it shows the correct STANDARD time. (All times referred to are standard time--one hour earlier than daylight saving time.) You can get the correct time from a radio broadcast or from the telephone company. Or your teacher may have a watch which has recently been set to match a time standard. If you use a radio or telephone in setting your timepiece, take a reading again when you get another time signal. This will serve as a check for accuracy.

B. Using the point of a drawing compass, punch a small hole in the sheet of paper. The hole should be about 2 1/2 inches in from the mid-point of a long side of the sheet. Insert the gnomon through the hole in the paper making sure that the entire sheet of paper is on the board. Using masking tape, tape the corners of the paper to the gnomon board in such a way that there are no folds or wrinkles in the paper. See Figure 2.2. Write the date and the names of your team members near one corner of the paper.

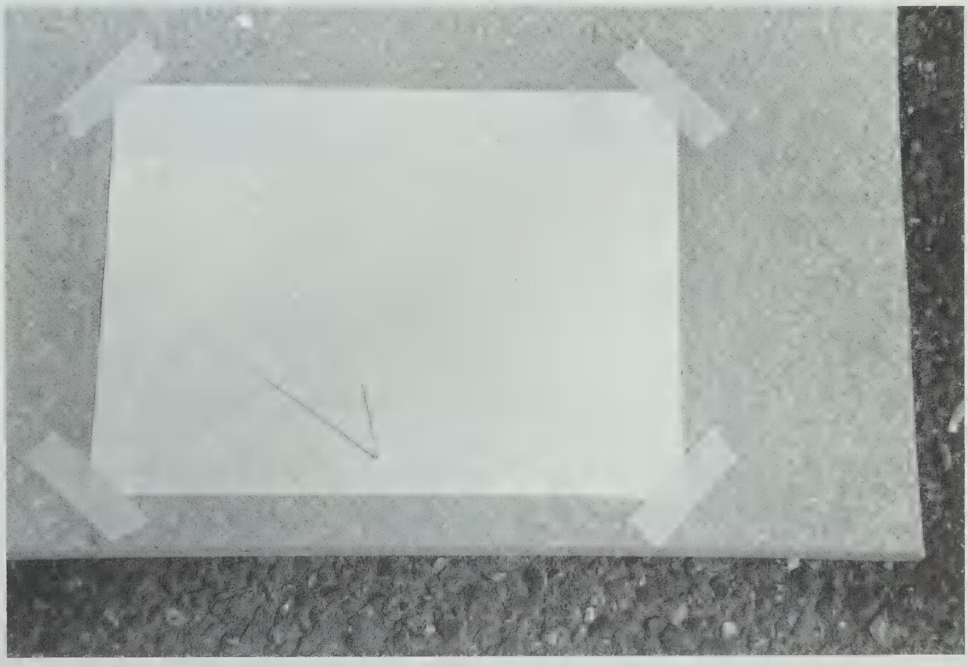


Figure 2.2. Gnomon Board.

C. Place the gnomon board where sunlight will strike it for several hours. Be sure the gnomon board is level. The starting position of the shadow should be about as in Figure 2.2. If the gnomon is placed on pavement, chalk marks can be made to help in returning the board to position in case it is moved. Ideally, the board should not be disturbed at all while it is in use.

D. Using a <u>sharp</u> pencil, mark the end of the gnomon shadow with a fine dot. Write the time next to the dot. You should begin between about 9:00 and 10:00.

Interpretations

1. What do you and your team's members think will be the path of the gnomon's shadow? Discuss your ideas. Then lightly sketch a line on the paper, showing the path you predict.

<u>Procedures</u> (continued)

E. Place a magnetic compass on the paper at one of the corners farthest from the metal gnomon (Figure 2.3). Turn the compass until the north end of the needle points to the <u>N</u> mark on the dial. Place a ruler next to the compass and draw a line parallel to the compass needle. Label this line "magnetic north." Return the compass to its proper storage place. Measure the height of the gnomon above the board and write it on the paper. This measurement may be needed in later work.

F. At intervals of about 30 minutes mark the location of the tip of the gnomon shadow. Write the exact time beside each mark. Make more frequent observa-

Figure 2.3.

tions between 11:00 a.m. and 1:00 p.m. Fifteen-minute intervals will do.

G. Continue the observations as late in the day as possible. When you have completed your observations, carefully loosen the tape and remove the paper from the gnomon board. Do not tear the hole. Return the gnomon board to its proper storage place.

Interpretations

2. Was your predicted path of the shadow line like the actual one?

3. What advantages do you think the use of a gnomon has over direct observation of the sun?

INVESTIGATION 2.1: The Gnomon

You should prepare a gnomon record for yourself as early in the school year as possible. Or if your school starts late, you may wish to prepare the record just before school starts. There are several reasons for this: Until you have actually made a record, the problems involved in having the students obtain one may not be clear. Weather in your area may become cloudy during the time you wish to have students do the work, and if you have made a record locally it will be possible to provide copies of it to the students. Even if students are able to prepare gnomon records at the time you would like them to do so, it will be interesting to have an earlier record for comparison following their work with Investigation 2.5, Indoor Gnomon--Axis Tilted.

The text assumes that in most schools the first student record will be made within a week of the fall equinox, September 21. If this is the case, the shadow line will be essentially straight and will agree with those produced by the Indoor Gnomons in Investigation 2.3. If the records are made quite early in the year, curvature of the shadow line may be apparent and your presentation will have to be altered slightly. See the Teacher Material accompanying Investigation 2.3.

Since there are so many variables which may affect your ability to have students perform this investigation--not the least of them being weather--it is recommended that you take your class out to gather the data on the first day it is possible to do so, interrupting the sequence of investigations in Section One if necessary. The records can then be saved and analysis performed at its proper time in the sequence. Once performed by the class, the investigation should be repeated at intervals of a month or so.

If time does not allow repetition by the entire class, one or two teams should be selected to perform the subsequent trials, perhaps on weekends as an extra-credit assignment. Their results may then be duplicated and passed out to the class.

At this point, it is not desirable to explain that at the equinox, days and nights are of equal length. If students comment that this time of year is the equinox, acknowledge it and explain that the significance of the equinox will be better understood after further investigations have been performed.

The method of scheduling the procedures in this investigation will vary depending upon the situation in your school. If you work with one group of students through a good part of the day, there is little problem. Students can set up the gnomons early in the day and later be given a few minutes at intervals to record the data.

If you have several science classes, those meeting in the morning can set up their gnomons during regular class time. Students may then be able to add additional data between classes, at recess, at noon, etc. If that plan is not practical, you may wish to have each student in your earliest class set out a gnomon. As other students come in during the day they can add data. The last class can bring in the data sheets and store the apparatus. You can then distribute the data sheets the next day, a few to each class, for interpretation of results.

Still another plan might be to ask students to make a complete gnomon record at home or at school (with your assistance) on a weekend.

If none of the foregoing plans seems workable, you could let all students go through Procedures A-F making as many shadow marks as time permits during a regular class period. Then distribute dittoed copies of a run that you have made. Students can carry out Investigation 2.2 on the dittoed copies.

If all else fails you can duplicate one of the samples included in the teacher material.

It should be remembered that one major emphasis of the course is on the methods by which scientific knowledge is developed. A scientist cannot rely on having data handed to him but must also know how to collect it. There is always the possibility that students receiving hand-out information will not understand the process by which it was obtained.

Materials

Protractors, compasses, rulers, and timepieces can be shared by several teams.

We see no particular educational benefit in having students construct the gnomon boards. This could be done by you in a very short time. Or you may find one or two students whose fathers have wood working shops and who would be willing to produce gnomon boards for your classes. You will need one gnomon board for each team.

CONSTRUCTION OF GNOMON BOARDS

1. Cut a one-inch thick, 12-inch wide board about 13 inches long.

2. Drive a small (6 penny finish nail) through a long side of the board about 2 1/2 inches from its edge and midway between the two ends of the board. See Figure T-2.6.

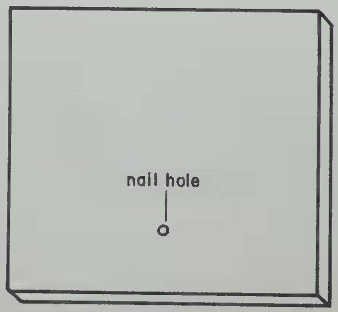
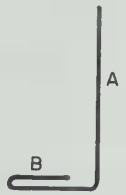


Figure T-2.6.

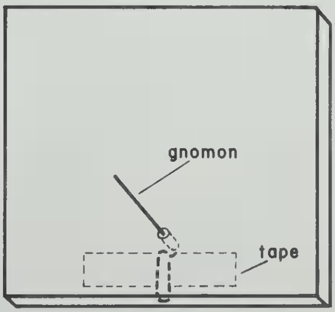
3. Remove the nail. (The holes can be drilled if an electric drill is available.) Unbend a large paper clip so that it will look like Figure T-2.7.

Figure T-2.7.



4. Place the long straight part of the paper clip (A) through the hole you made with the nail so that the bent part (B) is on the lower side of the board. Using masking tape, securely tape the bent part (B) of the clip so that when the board is in an upright position, A will point straight up. See Figure T-2.8.

Figure T-2.8.



Procedures

A. Do not rely on the room clock for accurate time-of-day. If you do not expect to have one timepiece for each team, plan to call out times from your own watch as the students mark shadow locations. But be sure to explain to the class the procedure by which you set your watch--whether you used a radio station's time, etc. Knowledge of correct time is essential to navigators who wish to locate themselves by observations of the sun; station WWV broadcasts time signals on a 24-hour basis. These signals can be picked up on most portable radios that have short-wave bands and can be heard at 5 megaherz, 10 megaherz, and other frequencies. Remind students that standard time is to be used in marking gnomon boards.

B. As the gnomon investigations are repeated later in the year, seasonal changes in the shape of the shadow line will become obvious. Remind students that data sheets are valuable only if dated.

C. On the day before the investigation is started, make sure that the gnomons will not be located near other objects which cast shadows on the boards during the critical noon-time period.

D. Small marks made with sharp pencils are essential for good results.

Interpretations

1. Responses will vary. Assure the students that they will not be penalized or ridiculed for incorrect predictions. The point is to show that careful observations of an often-seen phenomenon may lead to new insights.

Procedures (continued)

E. The procedure will depend upon the type of compass being used. When the results of the investigation are analyzed, students should be able to measure the "declination" of magnetic north--that is, the angle between true north and magnetic north at their location.

A board that is disturbed after Procedure E is completed can be realigned with a compass.

F. Until 11:00 a.m. dots may be plotted at any convenient times. However the exact time at which each mark is made should be recorded. From 11:00 to 1:00 it is better to plot marks at ten- or fifteen-minute intervals. This will make later calculations easier. Students should be encouraged to continue observations with a gnomon at home. However, if they do not intend using the equipment, it may be stored for future use.

G. A piece of masking tape on which one member of the team has written his name should be attached to the gnomon board. Thus the number of "variables" is reduced for future trials. Students should see that results obtained in future runs will be attributable to changes in earth-sun relationships rather than to the fact that a team is using different gnomons.

Interpretations

2. Answers will vary.

3. It is extremely dangerous to the eye to look directly at the sun but safe to look at its shadow. You can tell somebody where the sun rose and set but it is difficult to describe its location during the middle of the day because there are no nearby reference points. It is possible to make a written record from a gnomon shadow line.

Figure T-2.9

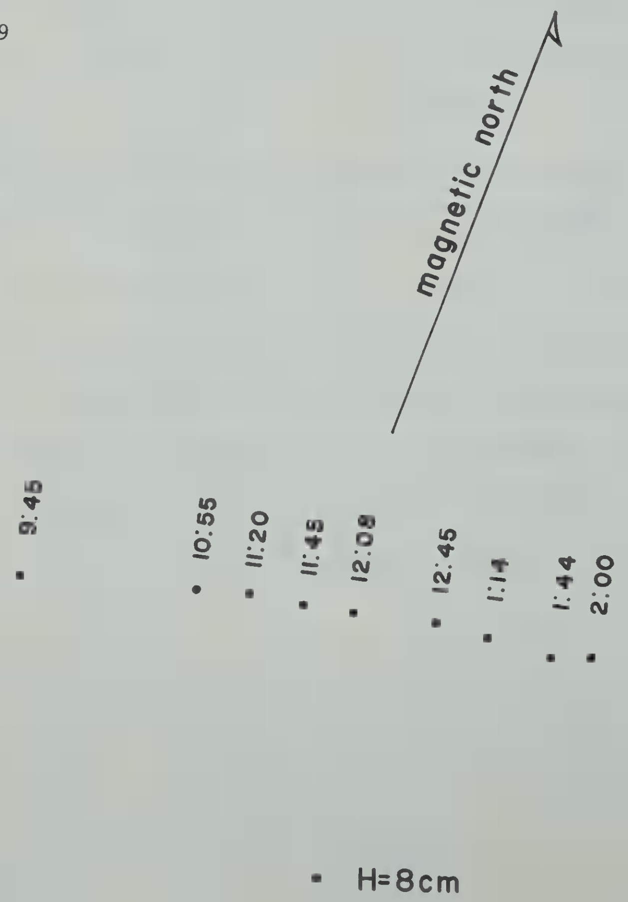


Figure T-2.10.

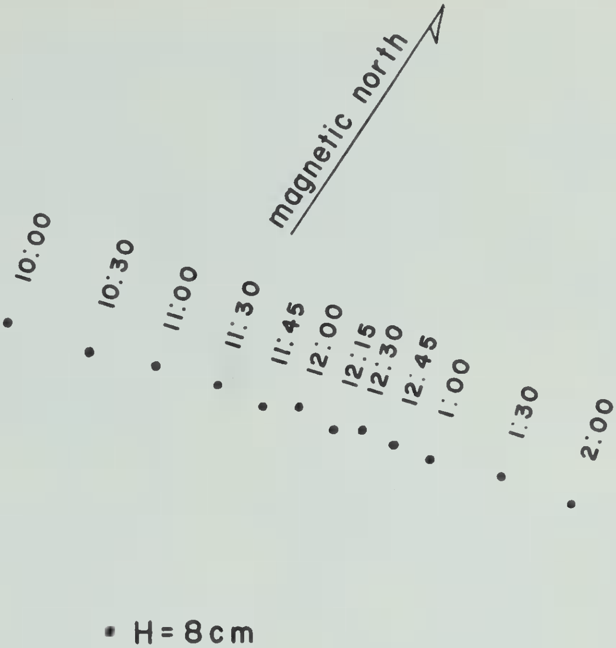
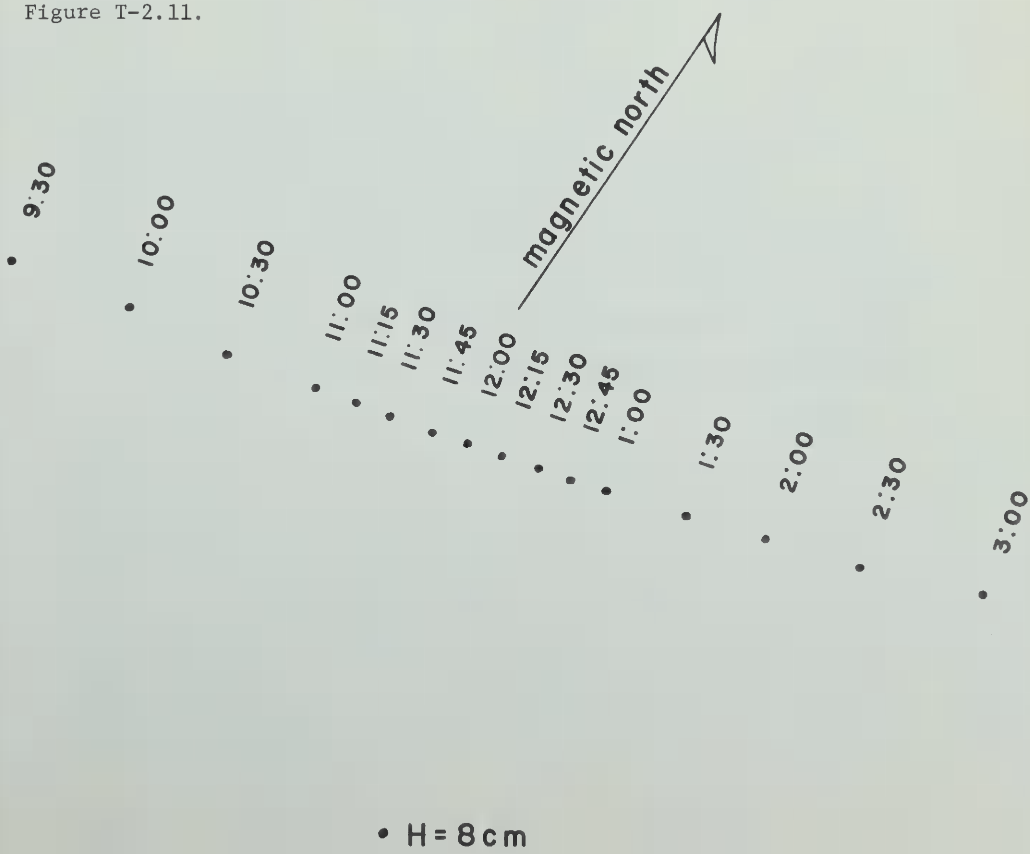


Figure T-2.11.



INVESTIGATION 2.2: Interpreting a Shadow Line

In Investigation 2.1 you obtained a record of the shadow produced by the sun and a gnomon. What do these observations mean? What can be learned by thinking about the observations? In other words, what interpretations can be made? The two processes of observation and interpretation often lead to new information. In this investigation you will attempt to interpret the observations you recently made.

Materials

Gnomon record prepared during Investigation 2.1
Drafting compass
Protractor
Metric ruler, flexible plastic

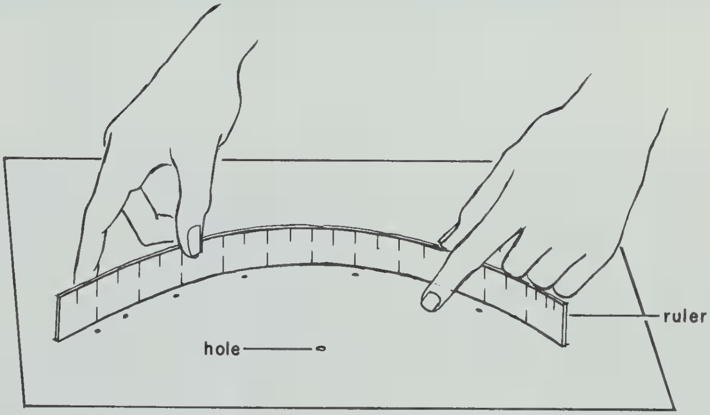
Procedures

A. Connect the dots marked on your paper during Investigation 2.1 by drawing a smooth curved line on the paper. One way to do this is shown in Figure 2.4. Have one team member hold a plastic ruler on edge and bend it to line up with the dots. A second student draws in the line. Make the line sharp and clean. Since this line marks the path followed by the tip of the gnomon's shadow, refer to it as the shadow line.

B. Find the point on the shadow line that is closest to the gnomon hole. A good way to do this is as follows: Place the pivot point of a drafting compass near the hole. Open the compass wide enough so that it will swing across the shadow line at two points

(A and B, Figure 2.5) about 10cm apart. Make short marks at these two points. Move the pivot point to A and draw an arc as shown in Figure 2.6. Do the same, using point B. Be sure the arcs cross each other (point C). Using the ruler, draw a fine line connecting the gnomon hole and point C (Figure 2.7). The intersection of this line and the shadow line should be the point on the shadow line nearest to the gnomon hole. Use your ruler to check that it is.

Figure 2.4.



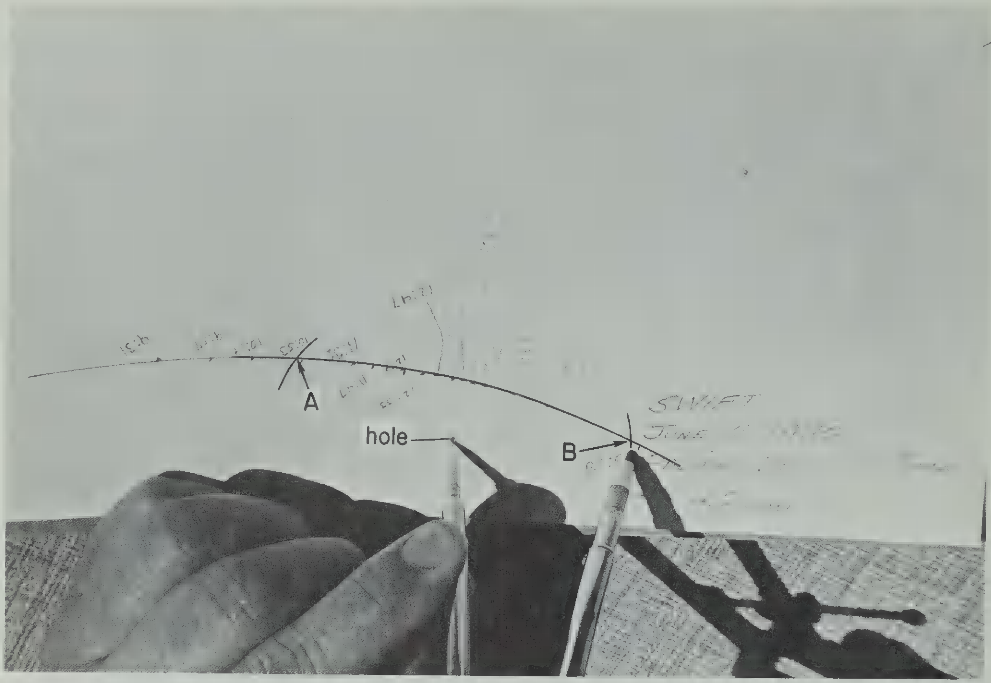


Figure 2.5.

Figure 2.6.

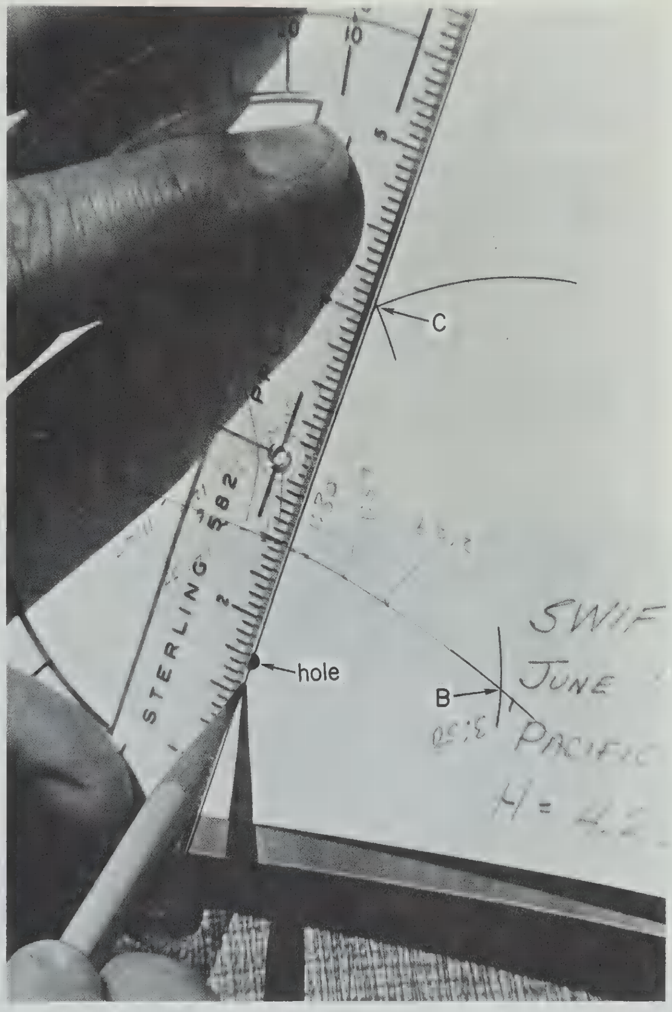


Figure 2.7.

C. The direction of the line marking the shortest distance from the hole to the shadow line is true north. If extended far enough the line would reach the north pole. This will be explained in a future investigation. Extend the true north line and the

magnetic north line until they meet. If they do not meet in a convenient place, you may draw a line parallel to the original magnetic north line as shown in Figure 2.8. Using a protractor, measure the angle formed by the true and magnetic north lines.

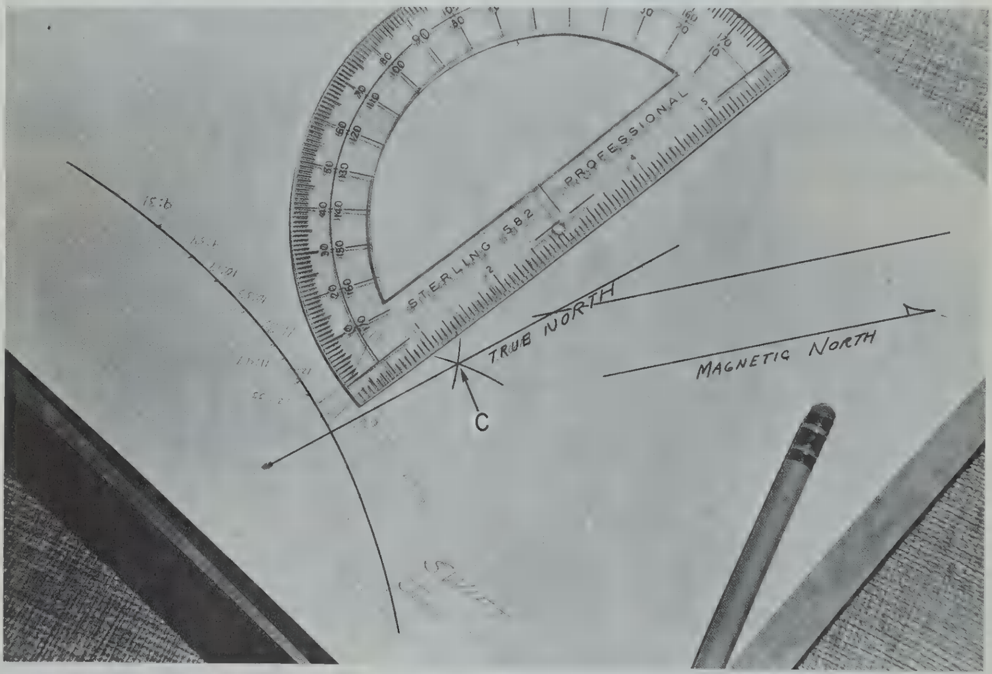


Figure 2.8.

Interpretations

1. At what time was the gnomon's shadow shortest? At what time was the shadow line closest to the gnomon?

2. What can you say about the height of the sun in the sky at this time of day?

3. Did the shortest shadow occur at exactly 12:00 o'clock?

4. Why do you think your answer to Interpretation 3 is correct?

5. What common name is often given to the time at which the gnomon's shadow is the shortest?

6. How many degrees are in the angle formed by the true north and magnetic north lines?

7. Does a compass point to the east or to the west of true north in your area?

FOR FURTHER ACTIVITY

1. As weather permits repeat this investigation at intervals of two weeks, or one month. Report any variations in your observations.

2. Observe the direction of the shadow of a tall object near your home at noon. This direction, almost true north, will be useful later in observing stars.

TEACHER
MATERIAL

INVESTIGATION 2.2: Interpreting a Shadow Line

The gnomon's shadow line is symmetrical and passes north of the gnomon, not through it.

The shortest distance from gnomon to shadow line (apparent solar noon) will not occur at exactly clock noon (12:00) except by coincidence.

Magnetic north and true north do not coincide in most localities.

Procedures

A. The pattern of the dots may be a straight line or a curve, depending upon the date on which the record was obtained. It is not likely that one smooth curve will fit all the dots exactly. Therefore some interpretation becomes necessary. In drawing the curve an attempt should be made to have equal number of dots on each side of the line. If all dots but one (or possibly a few) lie along a fairly smooth curve, the errant dots may be ignored. Perhaps they can be attributed to failure of the paper to lie flat, uncertainty due to fuzziness of the gnomon shadow, etc. In this and the next procedures (locating the closest approach of the shadow line to the gnomon) it is important that students not become over-involved in the method employed. Give whatever assistance is needed in finding the best curve and the closest approach so that student attention can focus on the shape of the shadow line and its significance.

B.-C. Students may need help in following these instructions. An example worked on the chalkboard may be helpful.

Do not allow students to become sidetracked by the geometric construction, which may be appealing to some.

Interpretations

1. Answers will vary.

Here the students should learn to interpolate, by mentally dividing up the time interval through which the line from the gnomon runs. An example is given in Figure T-2.12. This will be easier if readings have been made at short intervals and carefully labeled. Students should avoid making extra marks on the paper; these might later be misinterpreted as readings.

2. The sun is highest when the shadow is shortest. In early morning and late afternoon the sun is close to the horizon. At these times shadows are long. During the middle of the day shadows are short because the sun is high in the sky. If the sun were to pass <u>directly</u> overhead, the gnomon would not cast a shadow.

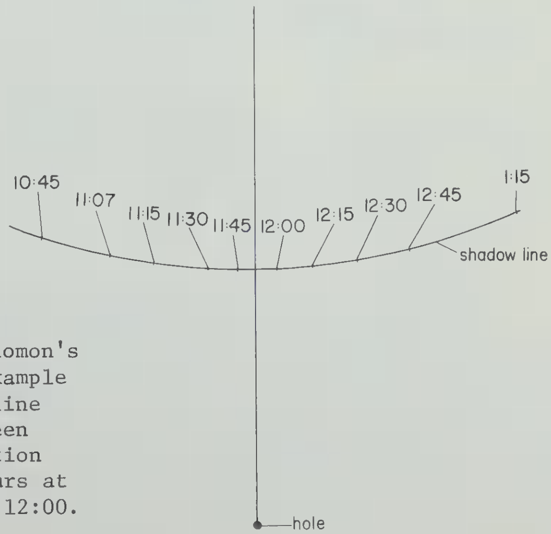


Figure T-2.12.

Finding the time at which the gnomon's shadow was shortest: In this example we can see that the true north line intersects the shadow line between 11:45 and 12:00. Closer inspection shows that the intersection occurs at a point about 2/3 of the way to 12:00.

2/5 x 15 minutes = 6 minutes.
11:46 + 6 = 11:51.

3. Answers will vary. In some locations the shortest shadow will occur at exactly 12:00 o'clock. In most places it will not. If the answers from a good number of teams average, say, 11:51, that is probably the "right" answer for your location--at least on this particular day. It is unlikely that the shortest shadow would occur more than 30 minutes before or after 12:00 noon--1:00 p.m. daylight saving time.

Some students may have seen through the problem and attempted to "bend" their results to fit the expected answer. Attempting to force data to fit a preconceived conclusion is not good scientific procedure.

4. Most students probably won't be able to explain why the shortest shadow did not occur at noon. If students suggest explanations, listen to them, but do not designate any answer as right or wrong. You might point out that the chances of all students making exactly the same errors are very small. Students should be encouraged to accept class data for the average time when the sun's shadow was shortest as most likely correct for their location. An explanation of this phenomenon will be presented in the discussion of time zones in Section Four.

5. This time is usually called "noon." Prior to this investigation most students have probably assumed that sun time and clock time were identical. Now they have a problem: Which noon _is_ noon?

6.-7. Answers will depend upon your location. There should be essential agreement among all teams. An approximate value can be obtained from Figure T-2.13. A more exact answer in degrees and direction for "declination" can be found by consulting a topographic map for your area.

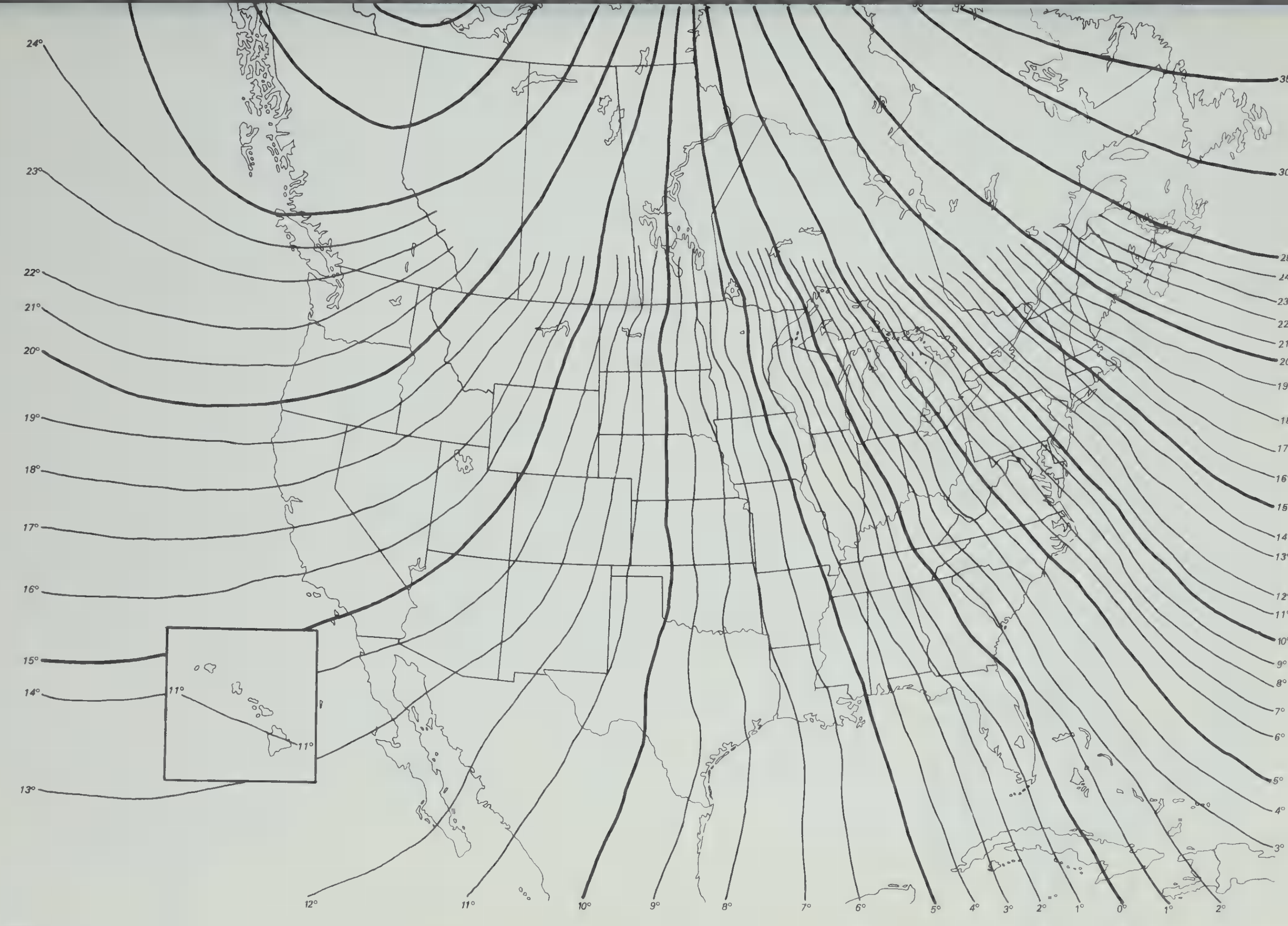


Figure T-2.13. Magnetic declination. [redacted]

FOR FURTHER ACTIVITY

1. At least once a month following the first run, ask students to repeat the procedures needed to obtain shadow lines. The date and gnomon height should be recorded on each data sheet. The sheets should be saved for analysis in January and February.

2. Knowing the direction of true north will be useful in Investigation 2.6.

UP AND DOWN

In a recent Inquiry Demonstration you were asked to think about words such as "north" and "east." It is easy enough to describe these directions in the classroom or outside, particularly if you have a magnetic compass. But it may be more difficult to think of what these directions would be for an observer at some point on a globe.

Now think about some other words: "straight up," "vertical," and "horizontal." What do they mean to you? What would they mean to a student in a far-distant country? What is their meaning at different places on a small globe?

It may seem a waste of time to bother with meanings of words which are used in common, everyday conversation. But scientists find it necessary to be precise (exact). They try to make precise observations. They also try to be sure that the meanings of words used to describe these observations are understood. By doing these things they can communicate their ideas with less chance of error or misunderstanding.

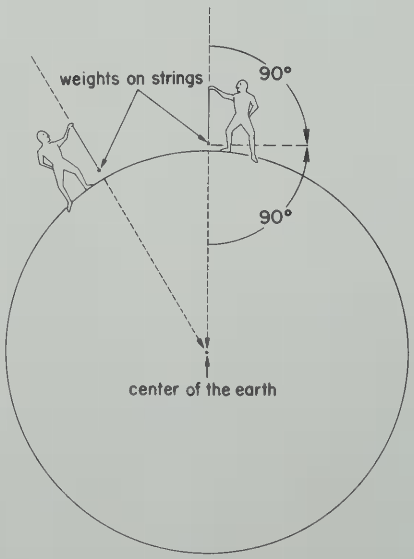


Figure 2.9.

<u>Vertical</u> refers to directions that are <u>perpendicular</u> to (or 90° from) the surface of the Earth. A string with a weight on one end and held stationary by the other end will hang vertically. Since the Earth's surface is curved, vertical lines at different points will not be parallel (Figure 2.9).

"Straight up" means away from the Earth along a vertical line; "straight down" means toward the Earth along a vertical line.

Now think for a moment about the term "level." Think of the meaning of the word in the phrase "level with your eye." You may or may not have thought about it in this way, but it is reasonable to define "level" as meaning perpendicular to vertical.

As you know, there are only two vertical directions--straight up and straight down.

How many "level" directions are there? Think for a moment: Are there two, or more, or less?

It is easy to see that there are more than two. There are many. North, south, east, and west are the main "level" directions. And there are many other level sub-directions, each of which may be described by its azimuth (see Investigation 1.2).

Just as "up" at one point is not parallel to "up" at another point, so "north" at one point may not be exactly parallel to "north" at another point. If this idea is not clear, test it out on your globe. Use two pencils or other pointers to indicate what is meant by "north" from two or more points. In most cases, the two pencils are not exactly parallel.

By the way, the word "horizontal" has the same meaning as the word "level."

The word "horizon" is a little more difficult. The "horizon" is an imaginary line running through all the points level with you as far away as you can see. Figure 2.10.

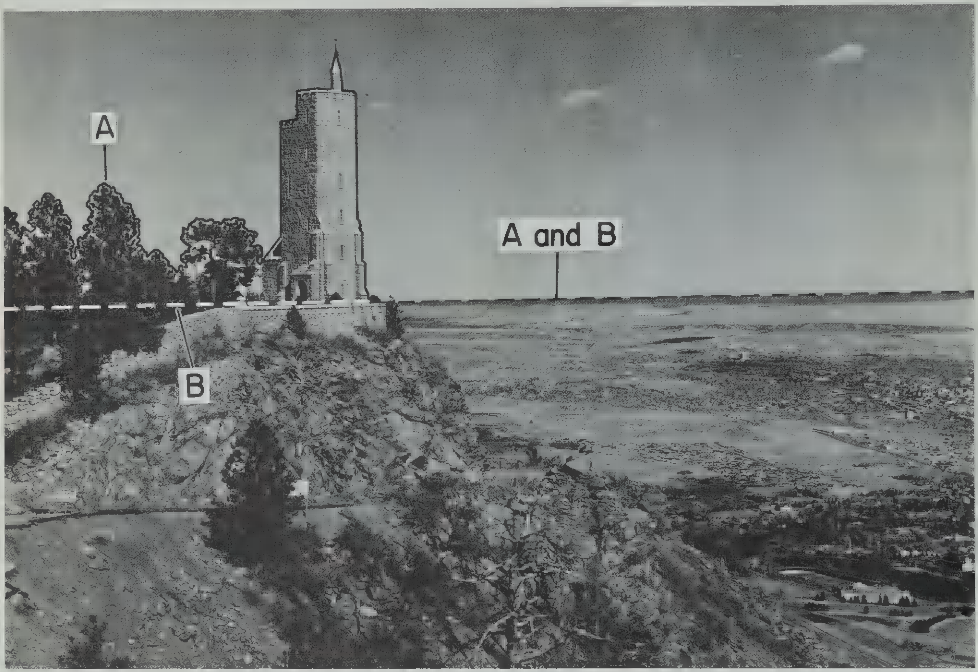


Figure 2.10. The boundary between earth and sky is often referred to as the horizon in ordinary conversation (line A). Over plains and oceans all points are level with an observer. When there are obstacles such as mountains, trees or buildings, the "level" horizon (line B) cannot be seen.

Sometimes "horizon" is used in a less accurate way--to refer to the line between sky and earth. If you are standing on a very large, level plain or on a boat at sea, the two types of horizons will be the same.

PROBLEMS

1. "Level" was defined as being perpendicular to "vertical." Give another definition for level by referring to water in a bowl.

2. What are the limits of usefulness for the word "up"? Could it be useful to astronauts in a space ship between two planets? Could it be used by astronauts who are on another planet?

3. Usually people who have globes (at least people in the northern hemisphere) like to place the globes with the north pole at the "top" of the globe. What are some reasons for doing this?

TEACHER MATERIAL

UP AND DOWN

This reading assignment is designed to ensure that the teacher, the students, and the authors are in agreement about the meaning of some common terms. If you are pressed for time, simply skip the assignment. Be sure, though, that you discuss with students what we mean by "horizon." There is some ambiguity about the term.

PROBLEMS

1. Level could be defined as "parallel to the surface of the water." Students may think of other ways to define the word.

2. Students should see that "up" can be useful even if it does not correspond to the usual notion of the word. For example, astronauts in a capsule in space would be deprived of the sensation of weight. Weight has been useful to the students as an indicator of "up" and "down." (A weight on the end of the string pulls the string into a vertical attitude. The weight of water in a bowl makes it unlikely that there will be any persistent deviations from a flat and level surface.) The astronauts might have an understanding that while in space one side of their vehicle will be referred to as "up," regardless of orientation of the craft (in relation to the earth). (Figure T-2.14)

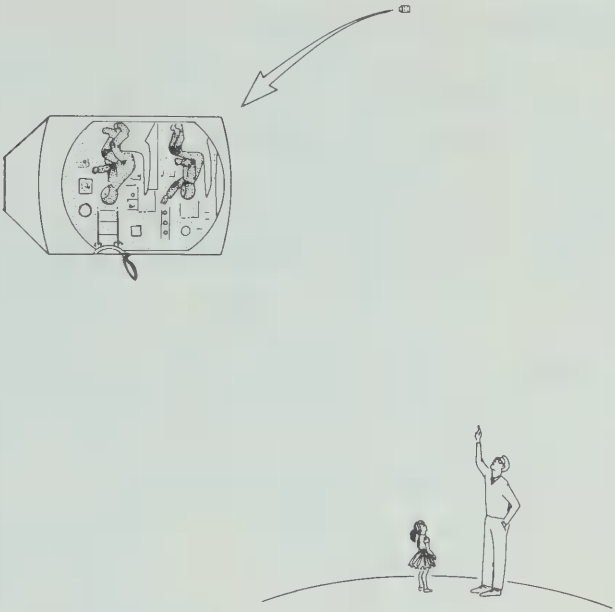


Figure T-2.14.
Both the astronaut and the man on the ground are pointing "up."

It would be logical for visitors on another planet to use a weight on a string to determine their "ups" and "downs."

3. With the globe in this orientation "up" for the room is roughly the same as "up" for North America on the globe. Thus a source of confusion is eliminated. This orientation is also a matter of convention and convenience. Printing on globes is designed to be read with the globe so aligned, possibly because most of the world's population lives in the Northern Hemisphere. You might wish to ask your students if they think that residents of Australia equate "up" with "north pole."

INVESTIGATION 2.3: An Indoor Gnomon

It is useful to think of the earth as a rotating globe. If you think of it in this way it becomes easy to understand why the sun appears to rise in the east and set in the west. Said in another way, a rotating globe is useful to represent the earth. Can the rotating globe be of help in understanding shadow lines produced by the outdoor gnomon? What information about "Where Are You" is contained in the shadow line? Answers to these questions may be found by carrying out this investigation.

Materials (per team)

Globe with axis and base
Scissors
Record of outdoor gnomon
Straight pins, 3
File card
Light source

Procedures

A. Use your globe to review the ideas presented in the Inquiry Demonstration about day and night. Decide which directions on your globe are to be called "north," "south," "east" and "west." Next decide the direction in which the globe should be rotated in order to produce "days" and "nights." In your notebook prepare a sketch showing these directions.

B. Following instructions given by your teacher, attach an indoor gnomon to a point in the "northern" hemisphere

(half) of your globe. Be sure that the miniature gnomon board is "horizontal" for that point on the globe. Also be sure that the indoor gnomon itself is "straight up and down" for that point. Check to be sure that indoor gnomon points directly "down" toward the center of the globe. There should be a 90° angle between the indoor gnomon and its gnomon board.

C. Around the base of the indoor gnomon draw short arrows labeled "N," "E," and "W." These arrows should point to directions on the globe, not in your classroom. See Figure 2.11.

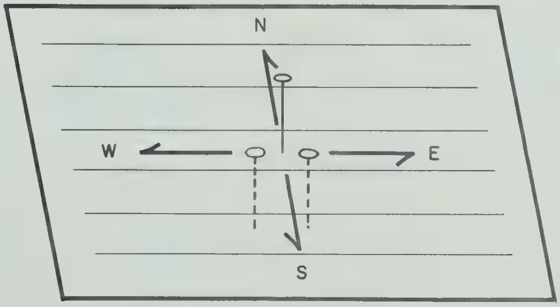


Figure 2.11. Procedure C completed.

D. Place the globe and base in front of the light source. Be sure that the globe is at the same height as the light and that the axis of the globe is perpendicular to the table top. Rotate the globe (in the "proper" direction) until the indoor gnomon shadow is in a morning position (about 10 o'clock).

Interpretations

1. In what direction from the indoor gnomon does the shadow extend?

2. Look at the record from the outdoor gnomon. In what direction from the outdoor gnomon did the shadow extend at about 10 a.m.?

3. Are your answers to Interpretations 1 and 2 the same or are they different?

<u>Procedures</u> (continued)

E. Rotate the globe on its axis until the indoor gnomon is in the "noon" position. Observe the length and direction of the shadow.

Interpretations

4. Did the indoor gnomon's shadow become shorter or longer as the globe was rotated from the 10:00 a.m. position to the "noon" position?

5. In what direction from the indoor gnomon does the shadow now extend?

Procedures (continued)

F. Look again at the record from the outdoor gnomon. Notice the length and direction of the shadow cast by the outdoor gnomon at noon.

Interpretations

6. Between morning and noon did the outdoor gnomon's shadow become shorter, did it become longer, or did it stay the same length?

7. At noon what was the direction of the shadow of the outdoor gnomon?

Procedures (continued)

G. Rotate the globe back and forth slowly between the morning and noon positions of the gnomon. Using a sharp pencil, trace the path of the tip of the gnomon's shadow on the file card. Now predict the afternoon path of the gnomon's shadow by drawing a shadow line where you think it should be. Slowly turn the globe all the way from the morning to a late afternoon position several times.

Interpretations

8. Was your prediction correct?

Procedures (continued)

H. Rotate the globe back and forth from "morning" to "evening" several times. If necessary make changes in your predicted shadow line. In your notebook make a sketch of the indoor gnomon's shadow line. Show both the shape of the shadow line and its relationship to the gnomon hole. Label it "Northern Hemisphere, Observed." Compare the shadow lines of the indoor and outdoor gnomons.

Interpretations

9. Other than in size, are the shadow lines similar or different?

10. If they are different, in what way are they different?

Procedures (continued)

I. In your notebook sketch a prediction of a shadow line at the equator. Label this sketch "Equator, Predicted." In making this prediction, you may look at the globe, but do not move the indoor gnomon yet. After making the prediction, move the indoor gnomon to the "equator" of your globe. Again be sure that the arrows point to the proper directions along the surface of the globe. Turn the globe through several "days," and observe the shadow. Make a sketch of the observed shadow line produced at the equator of your globe. Label it "Equator, Observed."

Interpretations

11. Was your prediction accurate?

12. Why do you think it would be difficult to use an outdoor gnomon near the north pole?

<u>Procedures</u> (continued)

J. Move the indoor gnomon to the "north pole" of the globe. Test the prediction you made in Interpretation 12.

Interpretations

13. Was your prediction accurate?

14. Do you live near the equator, near one of the poles, or somewhere in between? What evidence do the indoor and outdoor gnomons give you to support your answer?

TEACHER MATERIAL

INVESTIGATION 2.3: An Indoor Gnomon

An indoor gnomon mounted on a rotating globe produces shadow lines similar to those produced by the outdoor gnomon.

The strength of the model for the earth-sun relationship (thinking of the earth as being a rotating globe) is strengthened by this similarity.

Probable shadow lines which would be produced by outdoor gnomons at equator and poles can be predicted from the indoor gnomon.

Since shadow lines produced by the outdoor gnomon most closely resemble shadows produced by the indoor gnomon when it is in the "northern hemisphere" of the globe, students may reasonably conclude that they are located in the northern hemisphere of planet earth. This provides a partial answer to the question "Where Are You?"

Materials

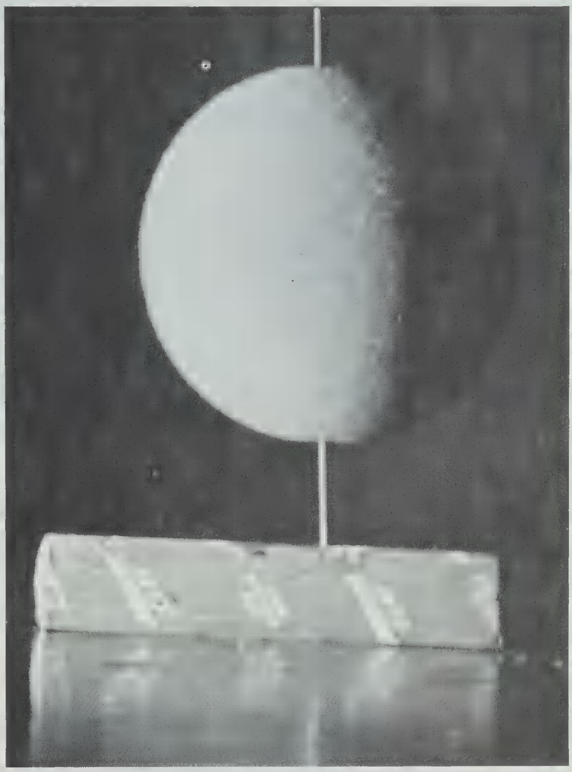
Although the materials described here have produced satisfactory results, others may work equally well. Detailed instructions for particular types of equipment are not provided in the student text. Give all the help you can in helping students set up apparatus that will perform satisfactorily. Give as little help as you must in telling students what they are seeing. Let them see for themselves.

Foam plastic balls (Nerf Balls) with a resilient surface, sold as toys which can be used indoors without damaging furniture make excellent globes. A three or four inch diameter is satisfactory.

Through such globes an eight inch length of straight coat-hanger wire may be inserted to serve as an axis.

As a base we suggest modeling clay or a piece of 2 x 4 with holes drilled at 90° and 35°. If the clay is left in its clear plastic wrapper it is less likely to be deformed or otherwise misused. See Figure T-2.15.

Figure T-2.15.



A 25-watt bulb, preferably unfrosted, will serve as light source for several teams. Be sure that electrical connections are not exposed, and that cords are taped to the work tables in such a way that the bulbs will not be pulled to the floor by an inadvertent tug on the cord.

Success of this investigation and, in large measure, success of Section Two depends upon students' obtaining clear-cut evidence from the globes and indoor gnomons. For this reason it is strongly recommended that you test the combination of globes and light sources you intend to have students use, in the classroom where they will use them. There are several ways of improving the sharpness of shadow lines: Moving the globe closer to the light source may help. Decreasing the overall illumination in the room may make the shadows more apparent. Replacing the bulb with one of higher wattage, or replacing a frosted bulb with an unfrosted bulb may help. If you suspect that light from the source is reflecting from walls of the room, you may be able to have students move toward the center of the room. If light from two or more of the sources falls on a globe it will make it more difficult to recognize the "correct" shadow lines.

An excellent method of eliminating extraneous light consists of cutting a cardboard carton to make three-sided partitions which fit around the globes. Ideally, the cartons should be covered on their inner surfaces with black construction paper. A removable top allows students to adjust the partitions to reach the proper compromise between maximum visibility of the globe and allowing too much light in. See Figure T-2.16.

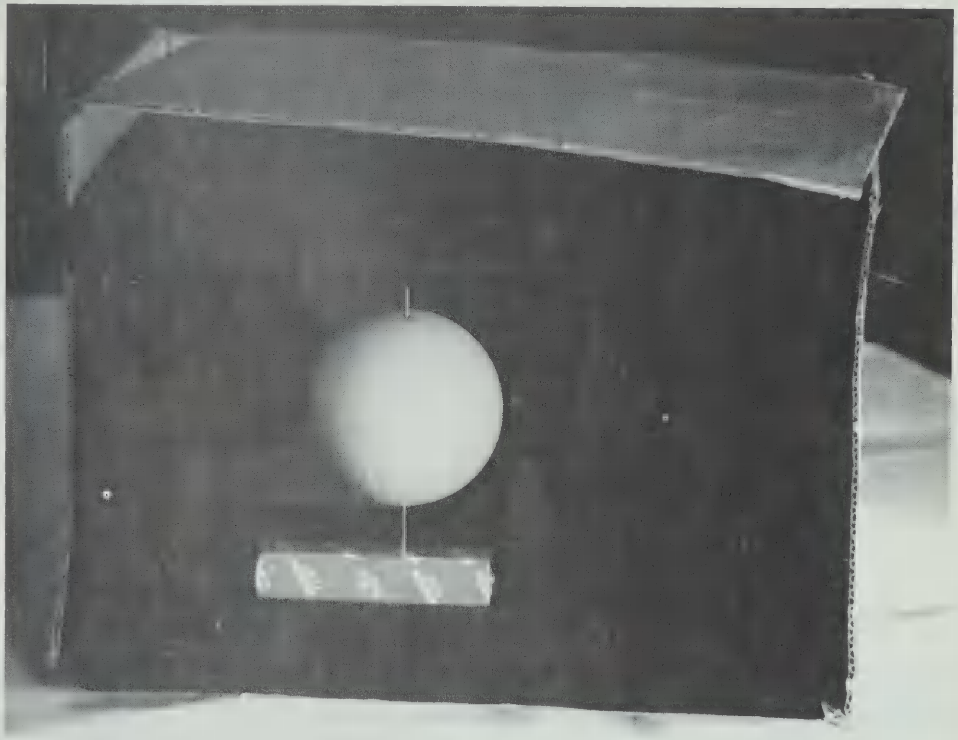


Figure T-2.16.

A 3" x 5" file card, cut in half, provides two satisfactory boards for the indoor gnomons. The cards should be used ruled side up. The card can be attached to foam rubber globes with two straight pins placed about 1/4" apart. These will ensure that the card lies "horizontal" to the globe at the point of contact and does not rotate or wobble. A third pin can be inserted between the other two, but only part way in, to serve as the gnomon.

Procedures

A. Five or ten minutes should be sufficient for this part of the investigation.

B.-C. No comment.

D. Students should not be overly concerned about the time of morning represented. Any point before "noon" at which a good shadow is obtained is satisfactory.

Interpretations

1. The shadow extends toward the northwest.

2. The outdoor gnomon shadow also extended toward the northwest from the gnomon at this time. If students experience difficulty be sure that they are considering the shadow itself (not marked except by the gnomon base and the 10 o'clock dot) and not the shadow line.

3. The answers should be essentially the same.

Procedures (continued)

E. No comment.

Interpretations

4. The shadow became shorter.

5. The shadow now extends toward the north.

<u>Procedures</u> (continued)

F. No comment.

Interpretations

6. The outdoor gnomon's shadow became shorter between morning and noon.

7. At noon the outdoor gnomon's shadow pointed north.

<u>Procedures</u> (continued)

G. No comment.

Interpretations

8. Student answers will vary.

<u>Procedures</u> (continued)

H. The sketch should be a copy of the indoor gnomon record.

Interpretations

9.-10. Student answers will vary. Under the conditions described, the indoor gnomon should be producing a straight shadow line. If it does not, check to see that students have placed the file card horizontal at point of contact, that the rotational axis of the globe is vertical, that the light source and globe are at the same height, and that the gnomon pin is directed toward the center of the globe.

The shape of the outdoor gnomon's shadow line will vary from school to school and will depend upon the date on which the record was produced. Shadow lines before the equinox and after the equinox will be curved, while those made sufficiently close to the equinox will be straight. Do not discuss this point with students at the present time as it will be developed in the next two investigations.

If indoor and outdoor gnomon shadow lines correspond in shape students would be reasonable in concluding that the indoor gnomon is lending strength to the rotating globe model. If shadow lines do not correspond, your outlook might be: "There seems to be something amiss. Since we cannot change the behavior of an outdoor gnomon we will have to consider changing the model." In Investigation 2.5 students will see that tilting the axis of the globe will result in curved shadow lines.

<u>Procedures</u> (continued)

I. The shadow line should be straight and will pass through the indoor gnomon position.

Interpretations

11. Student answers will vary.

12. Since shadows became very short at the equator it is likely that they would become extremely long at the pole.

Procedures (continued)

J. If the rotational axis for the globe interferes, a location near the pole should verify predictions.

Interpretations

13. Student answers will vary.

14. Students should recognize that they do not live near the equator because gnomon shadow lines at their location do not pass through the gnomon location. Neither do they live at a pole, because shadows are not inordinately long. Since the gnomon shadow at noon extended to the north, the sun must have passed to the south. Therefore it is reasonable to conclude that: "We live in the northern hemisphere, but not at the pole, of a rotating globe." This partial answer to the question "Where Are You?" will be refined later.

INVESTIGATION 2.4: The Length of Days

At any time of the year, a day--from noon till noon--lasts about 24 hours. But experience has shown you that during summer there are more hours of daylight than of darkness in each day. In winter there is less daylight in each 24-hour day. What could cause this? What changes would have to be made in the rotating globe model of the earth to account for changes in the length of days? In this investigation you will consider one possibility.

Materials (per team)

- Globe with axis and base
- Light source
- Rubber bands (5)
- Protractor
- Straight pins

Procedures

A. Copy Figure 2.12 in your notebook.

B. Place four rubber bands around the globe as shown in Figure 2.13. The rubber bands should be carefully placed to divide the globe into eight equal sections. Place a fifth rubber band around the globe to represent an equator.

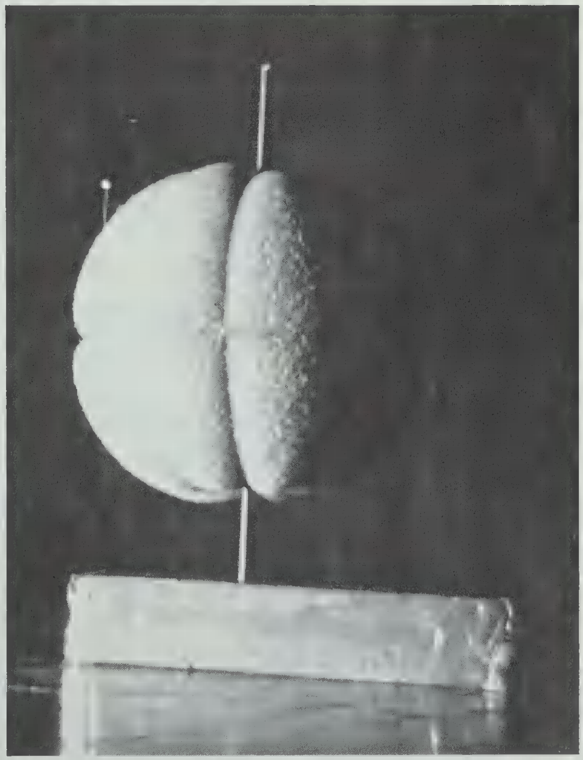
C. Stick a straight pin about half-way into the globe near the intersection of the "equator" with one of the "north-south" bands. Stick a second pin into the globe at a point about one third the way from the "equator" to the "north pole." The second pin should be along the same "north-south" band that the first pin was near.

Number of Daylight Hours

Location	Tilt Vertical No Tilt	Tilt Toward Light Source	Tilt Away From Light Source	Tilt To One Side Of Light Source
Equator Pin				
Northern Hemisphere Pin				

Figure 2.12.

Figure 2.13.



D. Put the globe in front of the light source. Be sure that the center of the globe is level with the light source and the axis is vertical (straight up and down). If it is difficult to see the line separating light from dark on the globe, ask your teacher for suggestions. The earth rotates once on its axis in each 24 hours. Imagine that your globe rotates at the same speed. Since the rubber bands divide it into eight equal parts, it would take $24 \div 8$ or three hours to turn from one rubber band to the next.

E. Rotate the globe until the equator pin is just coming from dark into daylight. Then rotate the globe slowly, counting "3 hour" sectors until the pin reaches the light-dark line. For how many "hours" was the pin in the light? (If you cannot tell exactly, estimate the number as closely as you can.) Enter the number of "hours" in the table in your notebook in the space labeled "equator" and "Vertical - No Tilt."

F. Repeat Procedure E, but this time observe the pin in the "northern hemisphere." Estimate the number of "hours" it spends in light and enter the number in the table.

G. Now tilt the axis of the globe about 35° <u>toward</u> the light source. (The "north pole" toward the light; the "south pole" away from it.) Check to be sure that the center of the globe is still level with the light source. Turn the globe to see how many "hours" each pin spends in light. Be careful not to change the tilt as you turn the globe. Enter your observations in the table.

H. Turn the base of the globe until the axis of the globe is tilted away from the light source. Test each pin in turn to see how many "hours" it spends in light. Enter your observations in the table.

I. Finally, turn the base of the globe until the axis is tilted neither toward nor away from the light source, but to one side. Estimate the number of "hours" spent in the light by each pin and enter these in the table.

Interpretations

1. Could changes in lengths of days on earth be accounted for by thinking of the earth as having a tilted axis?

2. If so, which season would correspond to which direction of tilt?

3. What can you say about the lengths of daylight for points on the equator if the tilt of the axis changes?

PROBLEMS

1. How do you think the lengths of daylight for a point near the north pole would be affected if the tilt of the axis changes? Does this agree with reports you may have heard about conditions near the pole?

2. In Procedure C, and elsewhere, words such as "equator" have been placed in quotation marks (" "). Why do you think this has been done?

TEACHER MATERIAL

INVESTIGATION 2.4: The Length of Days

A model in which the earth's axis is tilted (not perpendicular to the plane of the orbit) is consistent with observed seasonal variations in lengths of days.

Points on the equator of a globe experience 12 hours of daylight regardless of the inclination of the globe's axis.

Points farther from the equator experience greater variations in length of daylight.

Materials

The same globes and light sources used in the last investigation are suitable.

Rubber bands should be of a diameter which will fit the globe snugly.

Procedures

A.-C. No comment.

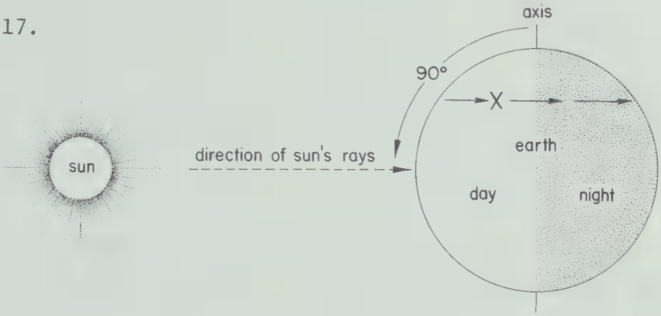
D. If students have difficulty in seeing the terminator, the line separating light from dark sides of the globe, suggest some of the techniques described in Investigation 2.3. Be sure that the terminator is well defined for the "no-tilt" condition, as it may become somewhat more difficult to observe when tilt is introduced.

E. Be sure that students rotate the globe in the direction which results in "sunrises" and "sunsets" occurring in their proper directions.

There may be some ambiguity about placing pins at the exact location of the dark-light line, but do not allow students to become too involved in the problem. The equator pin will spend about 12 "hours" in light during this procedure.

F. With the globe in this orientation the "northern hemisphere" pin will also spend about 12 "hours" in light. See Figure T-2.17.

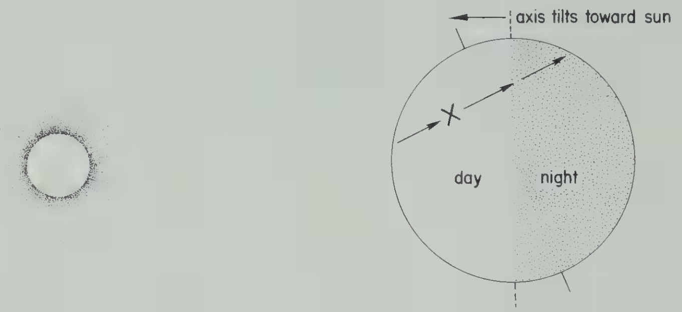
Figure T-2.17.



G. With the north polar axis tilted toward the light source the equator pin will still spend about 12 "hours" in light, but the northern hemisphere pin will be in light for more than 12 "hours." Students who have difficulty recognizing this may be able to see that the equator pin does spend 12 "hours" in light. By comparison they can then see that the northern hemisphere pin enters the lighted zone before the equator pin enters and leaves the light after the equator pin. Thus it must spend more "hours" than 12 in the light. If necessary tell students what to look for (the order of emergence

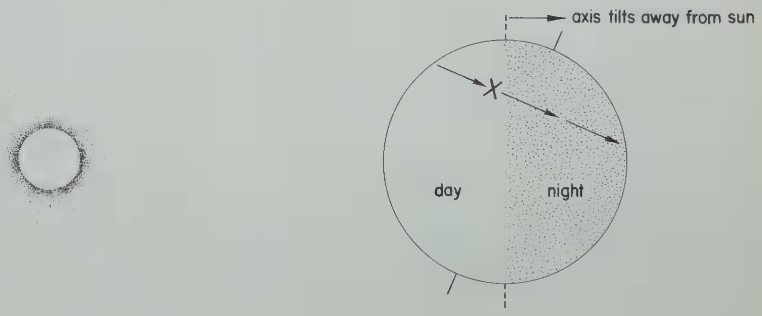
of the pins) but try to let them draw their own conclusions concerning lengths of time in light. The exact number of hours is not as significant as recognition of the fact that for the northern hemisphere pin, daylight time is increased.

Figure T-2.18.



H. Again the equator pin will be in the light for 12 "hours." This time the northern hemisphere pin will be in the light for significantly less than 12 "hours." See Figure T-2.19.

Figure T-2.19.



I. Students should be able to see that both pins spend the same amount of time, about 12 "hours," in the light. If students bring up the matter you could now discuss equinoxes, times at which all points on earth experience 12 hours of daylight and 12 of darkness. These occur on or about March 21 and September 21 of each year. If the matter does not arise of itself you might prefer to postpone discussion of the topic until students have completed Investigation 2.5.

Interpretations

1. Yes, thinking of the earth's axis as being tilted relative to the sun would account for daylight periods being shorter or longer than 12 hours.

2. The north polar axis inclined toward the light source would correspond to summer for the northern hemisphere. The north polar axis inclined away from the light source would correspond to winter for the northern hemisphere. Either the no-tilt or the tilt-to-the-side condition could correspond to spring and fall.

3. Points along the equator spend 12 hours in the light regardless of tilt.

PROBLEMS

1. Students may have noticed while performing the investigation that points near the pole experience continuous light when the pole is tilted toward the light source and continuous dark when the pole is tilted to the opposite direction. If they did not notice this, students may be able to infer the behavior of points near the pole from that of the observed points. Such conditions will probably be consistent with reports students have read, television shows, etc.

2. The equator is an imaginary line around the earth. The rubber band around the globe represents a line on the globe which in turn represents the imaginary line on the earth. In order to avoid such cumbersome use of words the rubber band is referred to as the "equator." Equator--without quotation marks--is reserved for the imaginary line on the real earth.

INVESTIGATION 2.5: Indoor Gnomon--Axis Tilted

A scientific model is first proposed to help in understanding an observation. The model is not generally proposed in finished form. As more observations are made, the model is changed to account for them.

Then an interesting thing may happen: A person may notice that some real event or thing can be predicted from the model. By "predicted" it is meant that according to the model something should be happening which no one has yet detected. When a model can be used in making predictions, there is a good chance to test the model. If the predicted observation is actually made, the strength of the model is increased. If new observations are not in agreement with the prediction, it becomes clear that the model should be improved.

Development of the earth-sun model is following the pattern just described. The model starts as a useful way of understanding why the sun rises and sets. The model is also found useful in understanding the general shape of shadow lines cast by a gnomon. The model did not at first account for an observation you had already made, that the number of daylight hours varies at different times of the year. In order to correct this the model was changed to include a tilted axis. This feature of the model, the tilted axis, may have made it easier to understand changing hours of daylight. But has tilting the axis destroyed the model's usefulness in explaining shadow lines? In this investigation you will consider the effect of a tilted axis on shadow lines.

Materials (per team)

- Globe with axis and base
- Light source
- Protractor
- Indoor gnomon
- Record made with outdoor gnomon

Procedures

A. Attach the indoor gnomon to a point in the "northern hemisphere" of your globe. Be sure that the gnomon base is "horizontal" and the indoor gnomon is pointing directly away from the center of the globe. Place the globe and gnomon in front of the light source. The axis of the globe should be vertical and the globe should be at the same height as the light source.

B. Rotate the globe and observe the shadow line which is produced. In your notebook make a sketch showing the shape of the shadow line and the location of the gnomon. Label the sketch "No Tilt."

C. Tilt the globe toward the light source by about 35°. Again rotate the globe and observe the shadow line. Make a second sketch in your notebook showing the shape of the shadow line and the location of the gnomon. Label this sketch "Tilt Toward Light Source."

Interpretations

1. Compare the two sketches. When the globe is tilted, does the shadow line at "noon" come closer to the gnomon, stay the same distance, or move farther away than at "noon" on the non-tilted globe?

2. With the globe tilted, is the shadow line straight, are the ends curved toward the gnomon, or are the ends curved away from the gnomon?

Procedures (continued)

D. Tilt the globe away from the light source by about 35°. Rotate the globe to produce a shadow line. In your notebook prepare a sketch showing the shape of the shadow line and the location of the gnomon. Label the sketch "Tilt Away From Light Source."

Interpretations

3. Describe what happens to the distance between shadow line and gnomon when the globe is tilted away from the light source.

4. Describe the shape of the shadow line when the globe is tilted away from the light source.

5. Examine the record from the outdoor gnomon. Does this record give any evidence concerning tilt in the earth's axis?

PROBLEMS

1. Describe an investigation you could carry out with a gnomon which might indicate whether or not the earth's axis changes its tilt in the course of a year.

INVESTIGATION 2.5: Indoor Gnomon--Axis Tilted

A scientific model may call attention to a hitherto undetected phenomenon.

The model of the earth-sun relationship has been changed (by adding a tilted axis) to account for variations in lengths of daylight. The effect of this change on shadow lines must now be re-checked.

The model predicts that shadow lines will be curved before and after equinoxes, but straight right at the equinoxes.

Materials

The materials are the same called for in Investigation 2.3.

Procedures

A. Be sure students understand that "horizontal" means level with the horizon for an observer at that point on the globe and not level with the floor of the room. The globe's axis should be vertical, with reference to the room, and the pin should be "vertical" with reference to the globe at the point of contact.

B. See Figure T-2.20.

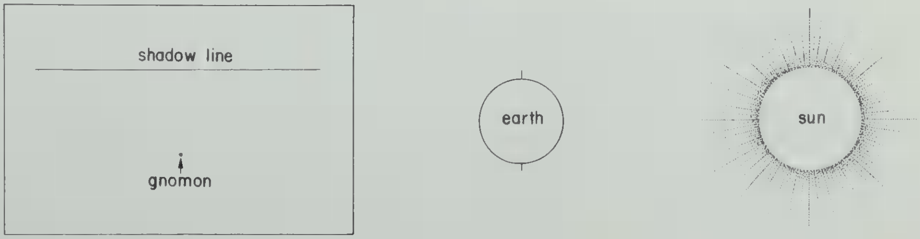
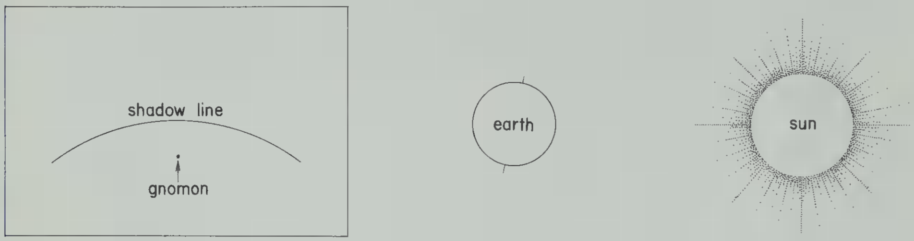


Figure T-2.20. No tilt.

C. See Figure T-2.21. Note that the distance separating shadow line from gnomon at closest approach has decreased and that the ends of the shadow line are curved toward the gnomon.

Figure T-2.21. Tilted toward the light source.



Interpretations

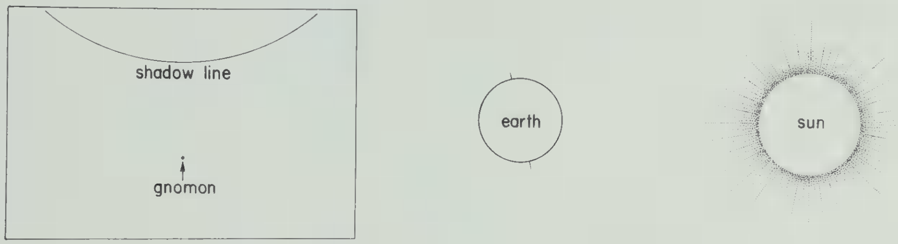
1. As the globe is tilted toward the light source the shadow line moves toward the gnomon.

2. With the globe tilted toward the light source the ends of the shadow line are curved toward the gnomon.

Procedures (continued)

D. See Figure T-2.22. Note that at closest approach the shadow line is now farther from the gnomon and that the ends of the line are curved away from the gnomon.

Figure T-2.22. Tilt away.



Interpretations

3. As the globe is tilted away from the light source the distance of closest approach of shadow line to gnomon becomes greater.

4. With the globe tilted away from the light source the ends of the shadow line are curved away from the gnomon.

5. Student answers will vary depending upon the time of year at which the gnomon record was made. From a single record it is not possible to make comparisons concerning distance of closest approach to the gnomon.

If records show a curved shadow line it suggests that the earth's axis may be tilted. Such curved shadow lines, of course, will not be obtained on or very close to the equinox.

PROBLEMS

1. Students may suggest that gnomon records could be obtained at intervals of a few weeks. Changes in distance of shadow line from gnomon, or changes in shape of shadow line would suggest a changing tilt. All records obtained should be dated and kept for use during the investigation, "The Sun Stands Still," which is found in Appendix D.

INVESTIGATION 2.6: The Northern Sky

Much information about the location and motions of the earth can be gained by observing the night sky. Although there are charts which show locations and motions of stars, there is no substitute for direct observation. Therefore, if you live in an area in which the night sky can be observed you should attempt to locate and observe some stars yourself. This investigation involves observing stars in the northern sky. You can find other suggested observations in Appendix D at the back of the text.

Procedures

A. Use a compass, a map, or the direction of a shadow at noon to locate north. Face this direction in the evening. With one arm, point to the northern horizon. Point your other arm straight up. Lower your upraised arm to a position half-way between straight up and the horizon, and extend a finger. The brightest star in the area you are pointing to is called Polaris. Other names for Polaris are North Star and Polestar.

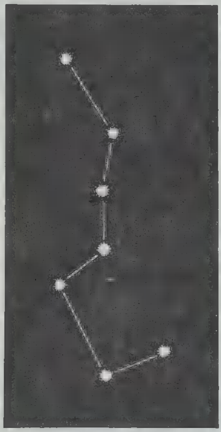
Interpretations

1. How would you compare the brightness of Polaris with that of other stars in the sky?

Procedures (continued)

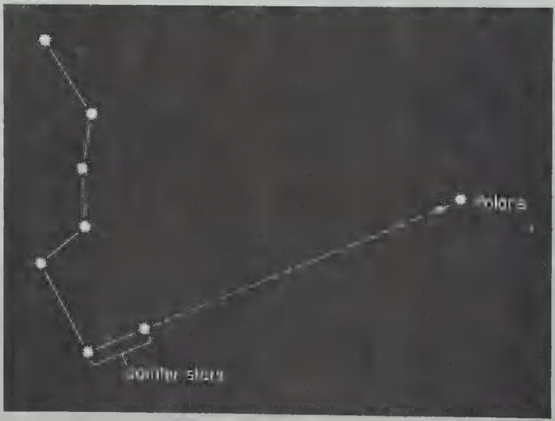
B. Look in the vicinity of Polaris for seven stars that make up a group called the Big Dipper. This constellation may not be in the position shown in Figure 2.14, but you should be able to recognize it from the pattern the stars form.

Figure 2.14. The Big Dipper.



Extend an imaginary line from the last two stars in the bowl of the star group, as shown in Figure 2.15. These two stars are called the Pointer Stars. If you have correctly located the Big Dipper, the line should lead to Polaris.

Figure 2.15.



C. Note the position of the Big Dipper relative to the North Star. Look again an hour later.

Interpretations

2. Did the Dipper appear to move clockwise or counter-clockwise? Star groups that move around Polaris are called <u>circumpolar</u>.

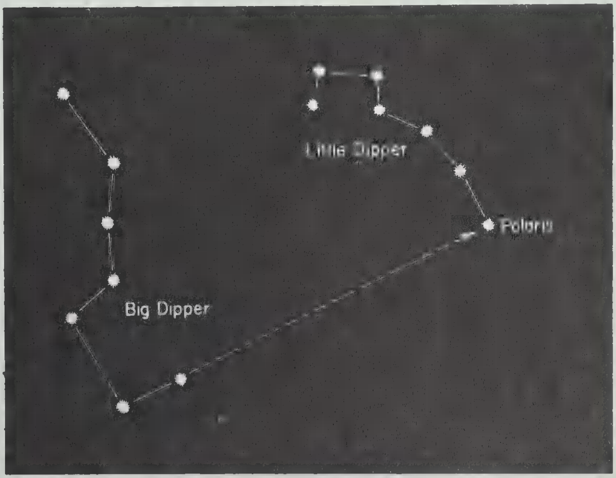
3. One of the seven stars in the Big Dipper is actually a "double" star, that is, two stars which are very close together. Which star is this? (Note: This is a difficult observation. It is possible only on very clear nights.)

<u>Procedures</u> (continued)

D. A second star group that is circumpolar is the Little Dipper. As its name suggests, it is not as large as the Big Dipper.

Because of viewing conditions, you may not always be able to see the Little Dipper. Figure 2.16 will help you locate it. Notice that Polaris is one of the stars in the Little Dipper.

Figure 2.16.



E. Draco the Dragon is a large circumpolar constellation. Unfortunately, it is also quite dim, but you should be able to see parts of it between the two dippers (Figure 2.17).

Figure 2.17.

Make a sketch of the positions of the three star groups or the parts of them you were able to see.

F. Two additional circumpolar constellations can be located and identified in the sky. To find Cassiopeia (Cass-ee-oh-pee-ya), extend an imaginary line from the first star in the handle of the Big Dipper, through Polaris, and continue for an equal distance past Polaris (Figure 2.18). Cassiopeia is shaped like the letter W or M.

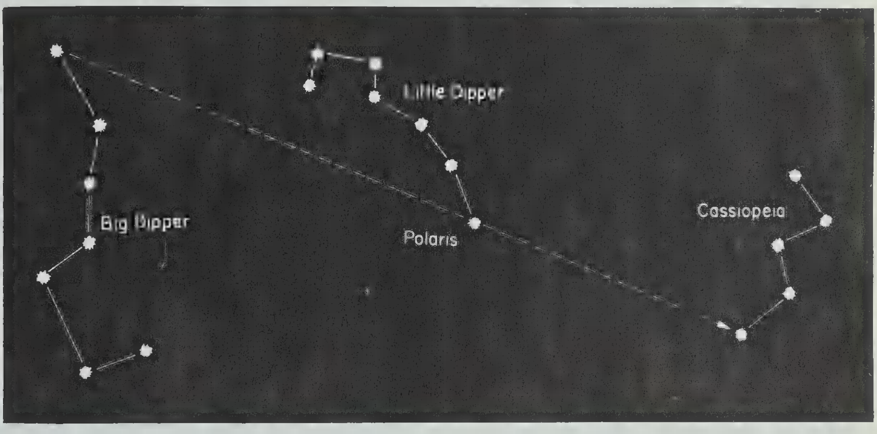


Figure 2.18.

G. The last circumpolar constellation you will look for is Cepheus (seh-phoos). Like Draco, Cepheus is difficult to see unless viewing conditions are very good.

Cepheus can be found between Draco and Cassiopeia (Figure 2.19). Five stars in the shape of a house or a pentagon make up this constellation.

Figure 2.19.

Figure 2.19 shows all the star groups described. Rotate the book until the star groups are in the same position as they were when you viewed them.

Interpretations

4. Which way would you have to turn Figure 2.19 (clockwise or counter-clockwise) to show the position of the stars one hour later? Through how many degrees would you have to turn Figure 2.19 to show this position?

5. Why do you think all the constellations examined appear to rotate around Polaris?

HINTS FOR OBSERVING STARS

Find a place away from bright lights. If this is not possible, try to stand where the lights do not shine directly on you.

Allow your eyes at least five minutes to get used to the dark. Your "night vision" will continue to improve for more than thirty minutes after you leave a lighted room.

If you use a flashlight to look at star charts or take notes while star-watching, cover the lens with a piece of red cellophane.

When looking for a dim object it may help to look slightly to one side of it. As you look directly at it, it may disappear. When you fix your attention to one side, it may reappear "in the corner of your eye."

INVESTIGATION 2.6: The Northern Sky

Polaris is observed as remaining stationary while adjacent stars move about it in a counter-clockwise direction.

Timing:

The investigation should be assigned at this time if it has not already been called to students' attention. The observations which are made will be needed before students work on Investigation 3.1. Assigning these observations of the northern sky a few days before related class work is begun will provide some leeway in the event of poor viewing conditions on one or more evenings.

The observations may be made by individual students, by groups, or--if interest is there--in a class star party. If skies in your area are consistently overcast you may wish to consider a planetarium field trip for your class.

Procedures

A.-B. If students are already familiar with the Big Dipper they should feel free to locate it first and then find Polaris by following the pointers. It is felt, however, that a student who has no prior experience with the northern sky can be led to find the star groups most easily by the method described here. In any event, the objective of the exercise is to observe the stars and their motions regardless of method employed to locate them.

Interpretations

1. Polaris is not a particularly bright star, but none in the vicinity is brighter.

Procedures (continued)

C. The Big Dipper appears to rotate counter-clockwise around Polaris.

Interpretations

2. See Procedure C above.

3. The next-to-last star in the handle of the Big Dipper, Mizar, has a faint companion, Alcor. Incidentally, Mizar itself can be resolved into two components with a telescope.

Procedures (continued)

D.-G. Students will probably find that Cassiopeia is the easiest of the four star groups to locate. Viewing conditions must be good to see the others, but at least parts of each group should be observed.

Interpretations

4. To see how the stars would look one hour later students must turn the book counter-clockwise through 15° ($360^\circ \div 24$ hours $= 15^\circ$).

5. A line extended from the earth's axis will lead almost directly to Polaris.

Section Three:

Testing Models

PREVIEW

Students have already found that a change in tilt of the earth's axis would result in varying numbers of daylight hours at different seasons. They have also found that a change in tilt of the axis would produce changes in shadow lines. Whether these changes in shadow line shapes and location have yet been observed depends to a great extent upon the number of gnomon records students have made and the length of time between such records.

Early in Section Three an Inquiry Demonstration shows three different models for tilting, that is, three ways in which the orientation of the earth's axis relative to the sun might change. None of the models is the familiar one in which the earth orbits the sun. Students observe that any of the three models is consistent with all evidence they have gathered to date.

One of the models, Model 1, is eliminated when it is found to be inconsistent with observations of Polaris. The observations of Polaris were suggested in the last section, but are summarized here in sketches in the student text.

A second model, Model 3, is eliminated when it is found to be at odds with observed changes in position of the Big Dipper through the seasons.

The remaining model, Model 2, is modified to account for observations of meteors and thus becomes the familiar and widely accepted current model for the earth-sun relationship.

Emphasis here should be on learning the manner in which models can be tested and on the basis for our current notion of the earth in orbit about the sun.

Encourage students who have not yet done so to observe the North Star and the circumpolar constellations (Investigation 2.5). Though anticipated observations are summarized in the text, it is in keeping with the philosophy of the course to encourage first-hand observation whenever possible. Observations of Polaris and the circumpolar constellations provide the basis upon which two of the models must be rejected.

NOTE: In the section following this one students will be concerned with longitude and latitude. It is recommended that teachers write to: Director, Coast and Geodetic Survey, Environmental Science Services Administration, Coast and Geodetic Survey, Rockville, Md 20852, attn: Seismology Division, requesting that they be sent the "Preliminary Determination of Epicenter Cards." The cards contain information which can be used to apply students' knowledge of geographic coordinates. The results of plotting this information will be useful in Section Ten, which deals with geophysics. The service costs $1.50. Payment should accompany your order.

Section Three:

Testing Models

Throughout Section Two the development of an earth-sun model was fairly straight-forward. The model proved useful in explaining certain observations you made; when the model failed to agree with new observations it could be quickly and easily changed so that it did agree.

You may have gained the impression that a model always develops in such a straight-forward fashion. If so, part of the reason may be that you have so far considered only one model at a time. That model may have seemed a description of what you already knew about the earth and sun before you started the course.

In Section Three you will consider several different models for the earth-sun relationship. Each model will be tested against observations which you have made or can make. Some models will survive these tests and others will not.

It is hoped that you will not simply learn which model is "best." You should come to know the strong points of each model, even the ones that are rejected. Finally, if one model does seem to be more useful than others, you should know why it is more useful.

TEACHER MATERIAL

TESTING MODELS

In Section Three, three different models for the earth-sun relationship are considered. As explained in the student text, this is done in order to show that there are possible alternatives to the accepted heliocentric model for the solar system.

None of the three models considered is the best current model. If one familiar and two unfamiliar models were presented, students might immediately accept the familiar model without understanding the basis for its usefulness. They might similarly reject unfamiliar models simply because they are unfamiliar rather than testing the models to discover inherent weaknesses.

In the reading selection "An Argument for Motion" the surviving model of the three is modified to conform to further observations and thereby becomes consistent with current thought.

INQUIRY DEMONSTRATION: Models of Tilting

In this demonstration your teacher will show you three ways in which it might be possible to think of the relationship between the earth and sun. You should try to decide whether each model is consistent with certain observations of the actual earth and sun.

Procedures

A. Copy Figure 3.1 in your notebook.

Strengths of Models

	Changing Lengths of Days	Shapes of Shadow Lines
Model 1		
Model 2		
Model 3		

Figure 3.1. Strengths of Models

B. Your teacher will demonstrate Model 1. In this model think of:

a) The sun being fixed in one location.
b) The earth fixed in another location, spinning on its axis once each 24 hours.
c) The earth's axis rocking back and forth along a straight line once in the course of a year.

Interpretations

1. Would Model 1 account for observations you have made concerning varying lengths of daylight? (Write "yes" or "no" in the table in your notebook.)

2. Would Model 1 account for any changes in shadow lines which you may have observed? Record your answer in your notebook.

Procedures (continued)

C. Your teacher will demonstrate Model 2. In this model think of:
   a) The earth fixed in one location but rotating on its axis once every 24 hours.
   b) The earth's axis as tilted but not changing its direction of tilt.
   c) The sun moving once around the earth in the course of a year.

Interpretations

3. Decide whether you think this model would account for changes in daylight hours and in shadow lines. Record your decisions in your notebook.

Procedures (continued)

D. Your teacher will demonstrate Model 3. In this model think of:
   a) The sun fixed in one location.
   b) The earth rotating on an axis which is not tilted.
   c) In the course of a year the earth moving once from a location above the level of the sun to a point below and then back up.

Interpretations

4. Decide whether you think this model would account for changes in daylight hours and in shadow lines. Record your decisions in your notebook.

PROBLEMS

1. Is it possible to decide, on the basis of the demonstration only, that any of the models is more or less useful than the others? If so, state which model seems more (or less) useful.

2. Describe any additional observations you can think of which might allow you to decide that one model would be more (or less) useful than any of the others.

3. Describe other models which you think might be as useful as these in explaining changes in shadow lines and lengths of daylight.

4. In investigations you have performed with the globe and light source you have been asked to keep the globe level with the light source. Why do you think this suggestion was included?

TEACHER
MATERIAL

INQUIRY DEMONSTRATION: Models of Tilting

Any of three models is useful in explaining observations concerning shadow lines and lengths of daylight hours. The fact that one model is satisfactory does not necessarily imply that others cannot be.

Materials

Globe
Light source
Annular ring

Before class be sure that the combination of light source and globe you intend using will be visible to the class. Practice manipulating the equipment until you can be confident of what the students will see even if you are standing behind the equipment where you cannot see.

Procedures

A. No comment.

B. Model 1 is illustrated in Figure T-3.1. If it is difficult for students to see the "terminator" (the day-night line) you may wish to use an annular ring to mark it. Such rings are provided on some classroom globes or may be fashioned from coat hanger wire. The ring should remain fixed while the globe rotates and tilts within it. See Figure T-3.2.

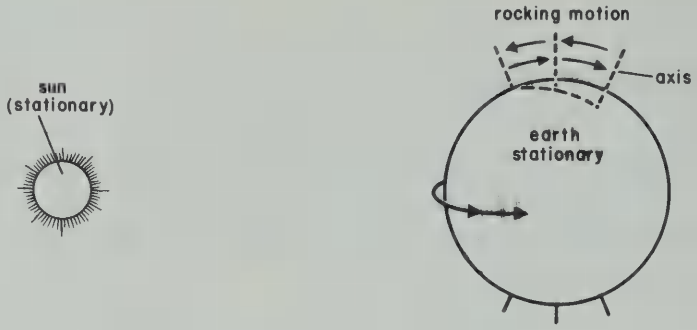


Figure T-3.1. Model 1:
a) The sun is fixed in one location.
b) The earth is fixed in another location, but spinning on its axis.
c) In the course of a year the earth's axis rocks back and forth once along a straight line.

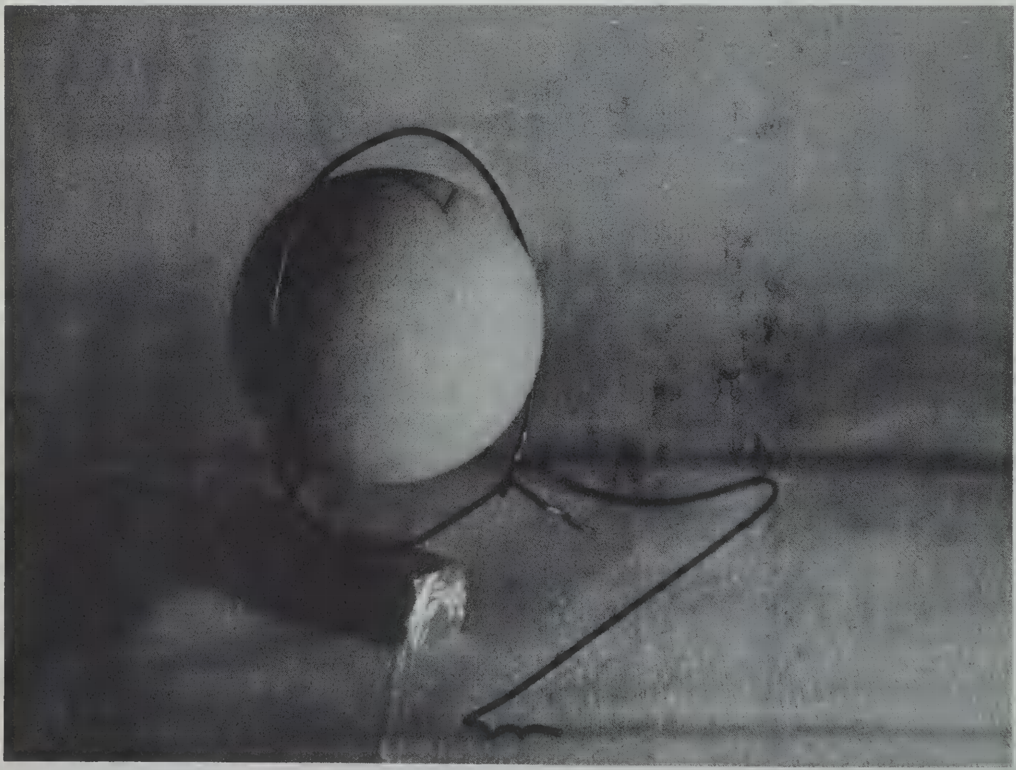


Figure-3.2. Annular Ring. Annular ring remains over terminator regardless of tilt of rotational axis of globe.

Interpretations

1. Yes, Model 1 is consistent with observed changes in length of day. If the axis of the spinning globe is vertical, each point on the globe's surface travels equal distances in light and darkness (refer to Figure T-2.17). Since the speed of rotation is constant, the equal distances correspond to equal amounts of time spent in day and night.

With the axis tilted toward the sun, each point in the northern hemisphere travels a greater distance--hence for a longer time--in daylight (Figure T-2.18). With the axis tilted away from the sun, every point in the northern hemisphere spends more than half of each 24-hour period in darkness (Figure T-2.19).

2. Yes, Model 1 produces the appropriate changes in shapes and locations of shadow lines.

A model similar to this one was tested by students in Investigation 2.4 (Indoor Gnomon--Axis Tilted) and was found to produce changes in the shadow line of an indoor gnomon. If students perform investigations with the outdoor gnomon throughout the year they will find that outdoor shadow lines are consistent with indoor shadow lines produced by this type of tilting. The same changes in shadow lines are produced by the other two models. Students who are <u>not</u> able to recognize this should be encouraged to use globes and light sources to test the models and verify results.

<u>Procedures</u> (continued)

C. Model 2 is illustrated in Figure T-3.3.

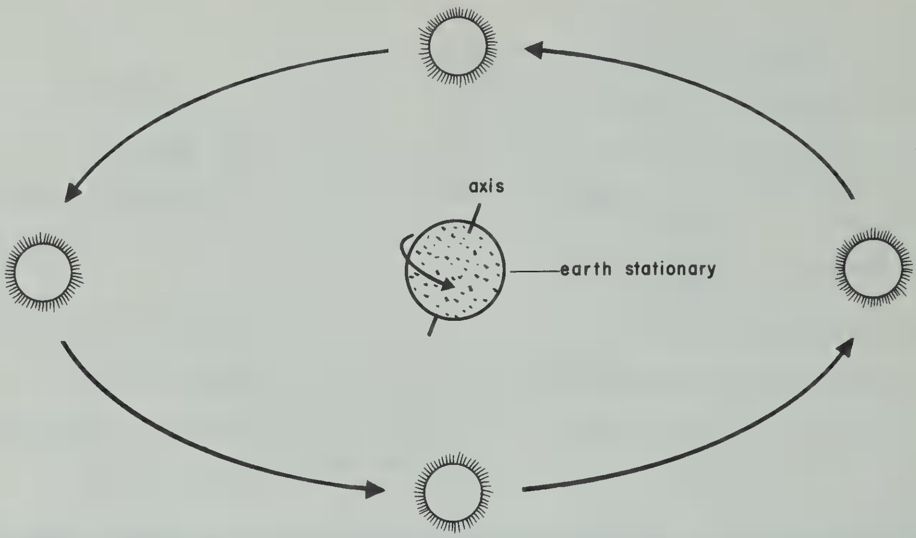


Figure T-3.3. "Sun" orbiting Earth.

Interpretations

3. Model 2 will also produce variations in lengths of daylight and shadow lines which are consistent with previous observations. Both spaces in the chart should be marked "yes."

<u>Procedures</u> (continued)

D. Model 3 is illustrated in Figure T-3.4.

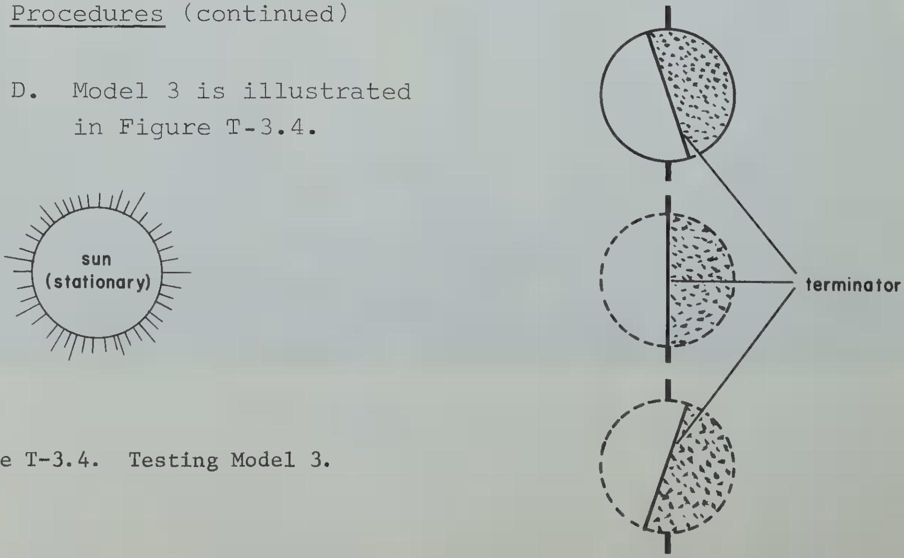


Figure T-3.4. Testing Model 3.

Interpretations

4. Again, "yes" is the appropriate response to both questions. Since the axis remains vertical in all positions but the tilt of the terminator moves, the effect is the same as that of tilting the axis.

PROBLEMS

1. On the basis of the demonstration it is not possible to conclude that any one model is preferable to the others. The same test has been made of all three, and each has "passed."

2. Student responses will vary. Some may suggest that observations of stars, other than the sun, might provide additional information. Withhold judgment on all suggestions.

3. Some students may suggest that a model in which a rotating earth revolves around a stationary sun once per year would produce the same effects. Other suggestions may be made. Again, take a "let's wait till we have tested it" approach.

4. As students should recognize from observing Model 3, allowing the globe to rise above or sink below the light source produces the same effect as does tilting the axis. Since an untilted condition was to be tested it was necessary that the globe remain level with the light source.

Students now know of (at least) three models for an earth-sun relationship which would give the results they have observed. You may wish to conclude your demonstration with a discussion of how each of the models could be further tested.

INVESTIGATION 3.1: The Strength of a Model

During the Inquiry Demonstration you observed three models of tilting that could be used to explain changes in length of days and in shadow lines. The strength or weakness of a model depends upon how many different types of observations may be explained with it. In this investigation you are asked to test the three models to see how well they can be used to explain observations of Polaris.

Materials (per team)

Globe
Straight pin
Masking tape

Procedures

A. Examine Figure 3.2. Three views of part of the night sky are shown as they would appear from the same location (possibly from quite near your home). In each case, the observer is looking in the same direction from the earth. The one thing that changes is the time of year. Notice that one star is always in the same position. The others change position. Do you recognize these stars? (Refer to Investigation 2.5.)

B. Now you need to test Model 1 to find out whether it agrees with what you know about Polaris. To do this insert a straight pin into the globe at some point in the "northern hemisphere" of the globe. The head of the pin should be pointing "north" and parallel to the globe's axis. This pin now represents a "line of sight" from an observer toward Polaris, the pole star.

Select an object or point on the ceiling which is in line with the pin. This point will represent Polaris.

Figure 3.2. Part of the sky as seen from the same location on three different nights.

C. Now make the axis of the globe rock back and forth as called for in part c of Model 1. Keep the pin pointed toward "Polaris" as the axis moves.

Interpretations

1. As your globe went through the rocking motion did the "line of sight" pin change its direction?

2. Is Model 1 consistent with observations of shadow lines, daylight hours, and sighting Polaris?

Procedures (continued)

D. Test Model 2 to see whether it agrees with what you know about Polaris. As in Procedure C, keep your pin directed toward a point which represents Polaris.

Interpretations

3. Is Model 2 consistent with observations of shadow lines, daylight hours and sighting Polaris?

Procedures (continued)

E. Test Model 3 to see whether it agrees with what you know about Polaris.

Interpretations

4. Is Model 3 consistent with all observations made so far?

5. Do any models seem less useful than others? If so, which ones?

INVESTIGATION 3.1: The Strength of a Model

Although most stars change location relative to the earth with changes in season or time of night, Polaris remains in the same location. The unvarying position of Polaris relative to the earth is not consistent with Model 1 but is consistent with Models 2 and 3.

Materials

The same globes used for investigations in Section Two may be used.

If the ceiling of your classroom is devoid of distinctive sighting points you may wish to put in some temporary "targets" before class.

Procedures

A. Here we are, in effect, making observations for the student. However, any who wish to make their own can easily do so. By "quite near your home" we mean in North America. Students who observe the circumpolar sky may notice that the altitude of Polaris as seen from their location may not agree with the drawings. This would be a commendable observation, but do not elaborate at this time, since Investigation 4.2 deals with this point.

B. If students comment that the axis and the line of sight cannot be both parallel and directed toward the same point, point out that Polaris is at a very great distance from the earth. Due to this great

distance--over 1000 light years--the distance separating an observer anywhere on earth from the axis is so small as to be negligible.

C. See Figure T-3.5.

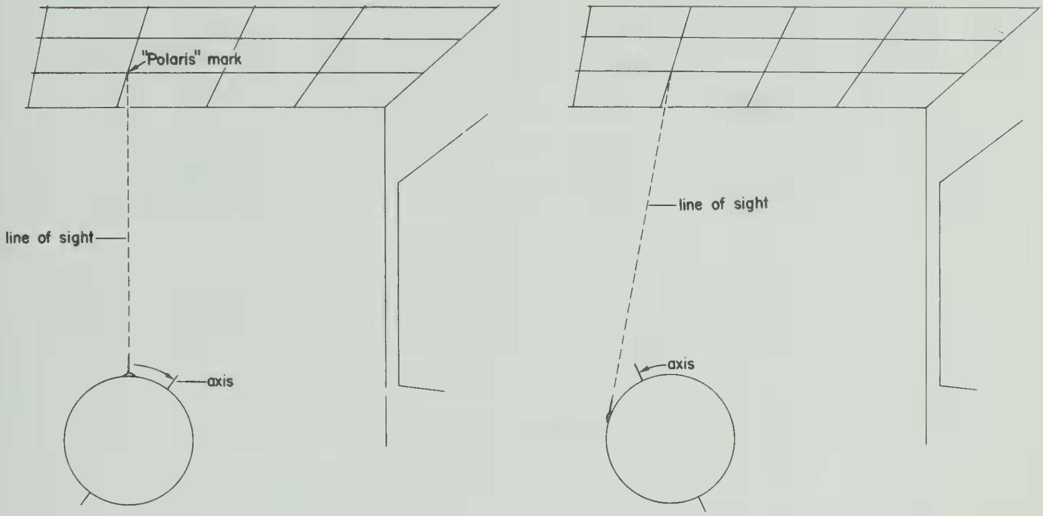


Figure T-3.5. Testing Model 1.

Interpretations

1. Yes, as the axis of the globe was rocked the direction of the line of sight had to be changed.

2. Model 1 is not consistent with sights of Polaris as shown in Figure 3.2.

<u>Procedures</u> (continued)

D. No comment.

Interpretations

3. Yes, Model 2 is consistent with all three observations. Since it is the light source and not the globe which is moved,

the line of sight does not change. Students who are troubled by the fact that the globe should be rotating can be reminded that after each full rotation, representing one day, the observer and line of sight are back to their starting position.

Procedures (continued)

E. No comment.

Interpretations

4. Yes, Model 3 is consistent with observations made so far, including those of Polaris.

5. Model 1 now seems less useful than the others. Models 2 and 3 are of equal value.

RELATIVE MOTION

At one time or another you may have experienced "relative motion." Perhaps you were riding in a car and noticed trees or power poles "rushing past." Actually, of course, they were not rushing; you were.

You may have ridden in an airplane and seen clouds "drifting by." Most of the motion was yours, not the clouds'.

Perhaps you have stumbled and seen the floor "come up to meet you." At least, the floor <u>appeared</u> to do so.

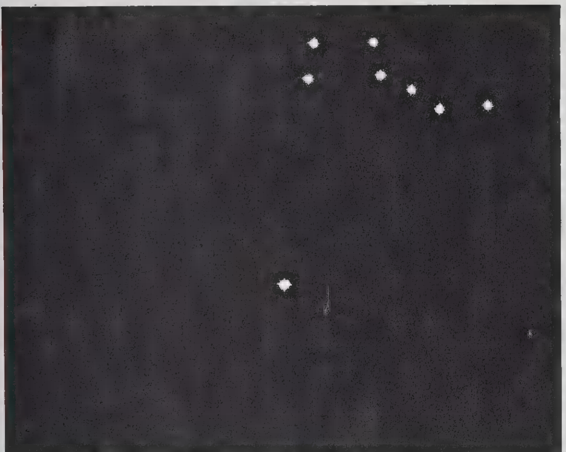
When a streetcar, bus or train starts with a jolt it is obvious that you have begun to move. However, if the vehicle starts very gradually there is no push from the seat-back to tell you that you have started. Your only clue to motion comes from your eyes. It may be difficult to tell, for a moment, whether you are moving forward or your surroundings are moving backward. On the other hand, if your vehicle remains stationary and one beside you starts forward you may get the feeling that you are rolling backward.

During the day the sun appears to move across the sky. At night stars seem to move. What is the actual case? Are objects in the sky moving, or is it the earth?

At times in history most people have believed that it was the stars which were in motion. At present, the accepted opinion is that the earth is rotating. It would be difficult right now to offer "proof" of either possibility. Later in the course, evidence for the earth's rotation will be presented. For the time being you are asked to think in terms of a rotating earth. Watch, though, for observations which would either support or discredit this model.

How can the idea of relative motion be put to use in understanding the motions of the earth in space? Examine Figures 3.3 and 3.4.

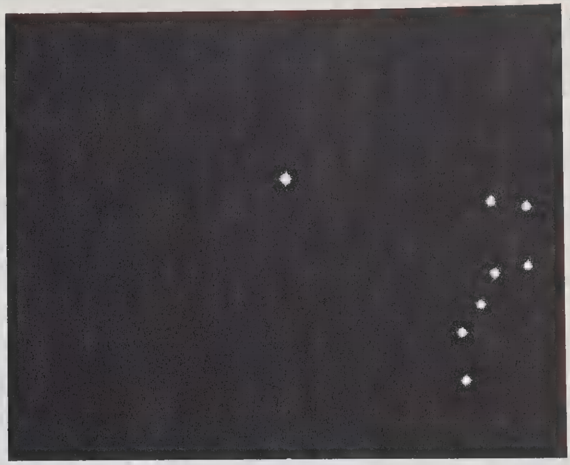
(a) Midnight, December 5



(b) Midnight, March 5

(c) Midnight, June 5

Figure 3.3. Polaris and the Big Dipper at midnight on three different nights.



(a) 6 p.m., March 5

(b) No information given

(c) 6 o'clock

Figure 3.4. Polaris and the Big Dipper at three other times.

Figures 3.3 a, b, and c show that in six months' time the Big Dipper moves in a half-circle. Your previous observations of the Big Dipper may have shown that the same type of motion would occur during the course of a single evening.

QUESTIONS FOR DISCUSSION

1. Suppose the change from Figure 3.4a to 3.4b results from rotation of the earth. What fraction of a complete rotation would be involved?

2. How many hours would this much rotation require?

3. What time of night March 5, would Figure 3.4b then represent?

4. If on the night of December 5-6 you saw the Big Dipper in the location shown in Figure 3.4b, what time of day would it be? (Hint: Look at Figure 3.3a.)

5. Figure 3.4c is labeled "6 o'clock." On what day of the year would the stars be in this position if this refers to 6 o'clock in the evening?

6. On what day of the year would the stars be in this position (Figure 3.4c) at 6 o'clock in the morning?

7. In addition to the _6 months'_ difference between Figures 3.3a and 3.3c, what number of _hours_ of rotation appears to have occurred?

TEACHER MATERIAL

RELATIVE MOTION

Motion of either the earth or stars might produce the observed apparent motions of stars. The fact of the earth's rotation is difficult to prove, so it will be considered an assumption temporarily. Polaris is located on an imaginary extension of the earth's rotational axis. The 180° shift in position of the Big Dipper over a six months' period is apparently the result of a one-half rotation of the earth on its axis.

"Proof" for motion of the earth about the sun (revolution) is offered in the section entitled "An Argument for Motion" which students will read in a short time. For the same reasons given in the Teacher Material accompanying that section, proof of the earth's rotation is difficult for students who are not conversant with Newton's Laws of Motion. The frequently described Foucault Pendulum may be mentioned by students. In the authors' view a description of this device, its behavior, and just what it proves and why would seem somewhat contrived to many junior high school students.

Later in the course the Coriolis Effect will be considered in conjunction with ocean currents and air masses. Again, this may not be entirely convincing to students.

Perhaps the best course to take is to encourage students to believe that the earth does rotate, but point out that their belief is founded on observations by others and not on personal observations.

QUESTIONS FOR DISCUSSION

1. This change in position would result from a one-quarter rotation of the earth.

2. One quarter of a rotation would occur in six hours.

3. Figure 3.4b represents midnight, March 5.

4. Again, Figure 3.4b represents a one-quarter rotation from Figure 3.3a. Adding six hours to the time of Figure 3.3a gives 6 a.m., December 6.

5. Figure 3.4c represents 6 p.m. on September 5. Several lines of reasoning might lead to this conclusion. Perhaps the easiest to follow would be: Since the stars are 180° away from 6 p.m. March 5 (as shown in Figure 3.4a), the seasons must have advanced by six months.

6. The stars would be in this position at 6 o'clock in the morning of March 5 or 6.

7. Twelve hours, corresponding to a one-half rotation of the earth, appear to have occurred.

INVESTIGATION 3.2: Choosing a Model

You may have found that all three of the models presented in the Inquiry Demonstration: Models of Tilting were consistent with observations of shadow lines and lengths of daylight hours. One of the models, though, was not consistent with appearance of Polaris at different times of the year. You then considered changes in position of the Big Dipper with changes in time and season. In this investigation you should find evidence favoring only one of the two remaining models.

Materials (per team)

Globe with axis
Straight pin
Blank paper
Object to represent light source

<u>Procedures</u>

A. On a sheet of paper mark eight dots to represent Polaris and the stars of the Big Dipper. Your diagram should resemble Figure 3.5.

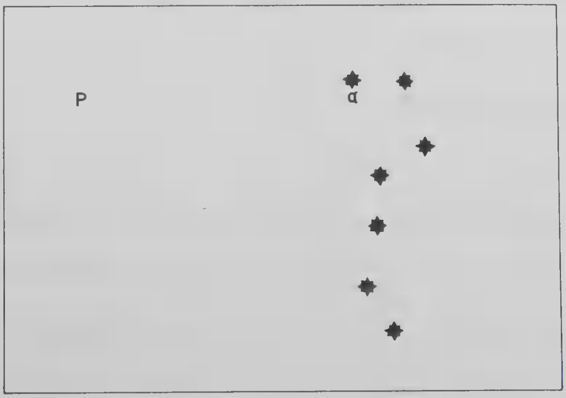


Figure 3.5. Big Dipper and Polaris.

B. Place a straight pin in your globe to represent a line of sight to Polaris for an observer in the "northern hemisphere." Set the globe in your work space with the axis tilted slightly from vertical. Hold your star chart over the globe. The chart should be positioned so that the observer (represented by the pin) would see Polaris and the Big Dipper in their correct relationship.

Interpretations

1. Toward which "star" on the chart should the axis of the globe be pointed?

<u>Procedures</u> (continued)

C. Rotate the globe 1/4 turn in the correct direction to produce "sunrise" in the "east."

Interpretations

2. How many hours would be required for this 1/4 rotation?

3. For the observer, would this rotation cause the position of the Big Dipper to change in the proper way?

<u>Procedures</u> (continued)

D. Place the globe and the object representing a light source next to each other. Rotate the globe until the observer pin is in the midnight position. Hold the star chart over the globe in a position such that the observer would see the Big Dipper as it appears at midnight on December 5. (Figure 3.3a)

E. Rotate the globe until the stars on the chart would appear to the observer as in Figure 3.3c.

Interpretations

4. How many hours of rotation were required for Procedure E?

5. Is it still "midnight" for the observer's pin?

Procedures (continued)

F. Keeping the globe and star chart in the positions they occupied at the end of Procedure E, move the "light source" until it is again "midnight" for the observer.

Interpretations

6. How many months would be required for the change in relative positions of earth and sun which you represented during Procedure F?

7. Which of the three Models of Tilting was represented by the change in positions you made during Procedure F?

8. Would either of the other models be useful in accounting for the change in position of the Big Dipper between midnight December 5 and midnight June 5?

9. Which model best fits all of the observations which have thus far been made?

PROBLEMS

1. Describe any other models which you think would be consistent with all observations made thus far.

TEACHER MATERIAL

INVESTIGATION 3.2: Choosing a Model

Apparent seasonal changes in position of the Big Dipper are consistent with Model 2, but not with Model 3 (or Model 1).

In this investigation students use globes and star diagrams, tangible representations of the earth and sky, to clarify the abstractions dealt with in "Relative Motion."

Materials

It is suggested that an "object to represent light source" be employed. This is done to minimize physical problems relating to power cords. The assumption is made that students will be able, after previous work with globes and light sources, to visualize the "midnight" location on the globes without an operating light source. If you wish, and if your equipment permits, actual light sources may be used.

Procedures

A. No comment.

B. By "in their correct relationship" is meant that the axis should be directed toward "Polaris" on the chart. The observer's line of sight, as represented by the pin, should be roughly parallel to the globe's axis.

Interpretations

1. The axis should be directed toward "Polaris."

<u>Procedures</u> (continued)

C. No comment.

Interpretations

2. Six hours would be required for 1/4 rotation.

3. Yes, if the globe is rotated in the correct direction to produce "sunrises" in the "east," apparent motions of the stars will be in the proper directions also.

<u>Procedures</u> (continued)

D. The midnight position would place the pin on the side opposite the light source. The chart should be held with the Big Dipper to the observer's right of "Polaris."

E. One-half rotation of the globe is required.

Interpretations

4. Twelve hours would be required for this amount of rotation.

5. It is no longer "midnight," but "noon" for the observer. This can be deduced from the observer pin being on the side of the globe facing the light source.

<u>Procedures</u> (continued)

F. This involves moving the "light source" around to the opposite side of the globe.

Interpretations

6. The relative positions of sun and earth change by this amount in six months.

7. Model 2 was represented.

8. Neither Model 1 nor Model 3 would account for the half rotation of the Big Dipper as seen at midnight on dates six months apart. Students should be encouraged to use their globes in verifying this answer.

9. Model 2 is consistent with all the observations thus far made.

PROBLEMS

1. Students may propose a heliocentric model, one in which the earth moves around the sun. If so, they may have problems in maintaining the direction of the globe's axis toward the star chart. You should explain that, because of the very large distances between the earth and the stars represented by the chart, there is no apparent shift in position of the entire group of stars. The next reading selection will present evidence favoring the heliocentric model over the geocentric model (Model 2) which has been strongest thus far.

Students may propose still other models. These should be tested to find their strengths and weaknesses.

AN ARGUMENT FOR MOTION OF THE EARTH

The next time you are riding in a car during a rainstorm, observe the front and back windows. While the car is stopped, drops will fall on the rear window and on the windshield at almost equal rates. But as the car moves forward, a greater number of drops will hit the front windshield. Fewer drops will fall on the rear window.

A similar sort of thing happens if you run through a rainstorm. More drops will hit the front of you than the back.

A moving object (such as you or a car) tends to run into drops which otherwise would have fallen in front of it. The moving object outruns drops that might have hit its back surface.

Space around the Earth has showers, too. These are not rain showers but clouds of tiny particles moving at high speeds. If they enter the Earth's atmosphere, friction with the air heats them up and causes them to glow brightly. During daylight hours we cannot see the glow. But at night the sky is occasionally pierced by a streak of light, and an observer says that he has seen a meteor.

Imagine that Earth is spinning on its axis but not moving through space. Occasionally it is struck by a shower of meteors. The direction the particles come from is partly a result of the direction in which they were originally moving. As they come near Earth, gravity pulls them downwards. On the average, over a period of time, all sides of the Earth would be hit by about the same number of particles.

During daylight hours you see few meteors. The meteors may be there, but the sun is so bright you cannot see them. When the spinning of the Earth carries you around into the night, you are able to see the meteors. If the Earth is not

moving through space, you would be as likely to see meteors just after dark as at any other time of night. (Figure 3.6)

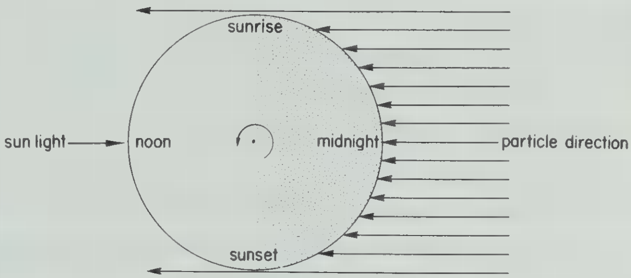


Figure 3.6. Particle shower striking a non-moving Earth.

Now suppose the Earth is moving through space as it spins. When it happens to run into a shower of particles, more of the particles will strike the "front" side of the Earth. This is similar to larger numbers of raindrops hitting the front side of a moving car. (Figure 3.7)

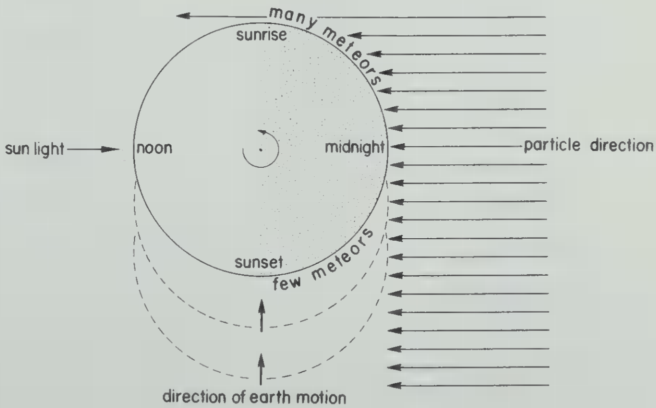


Figure 3.7. Particle shower striking a moving Earth.

On Earth, which actually happens? Are meteors seen in equal numbers all during the night? Or is there a "front" side to the Earth, making it more likely to see meteors when you are on that side?

Persons who spend a lot of time looking at the night sky observe more meteors between midnight and sunrise than between sunset and midnight. In the hour before sunrise, about four times as many meteors are seen as in the hour following sunset. This suggests that the Earth is moving and tells something about the direction of motion. Apparently the Earth is moving in such a way that sunrise is always on the front side.

Because meteors are most frequently seen just before sunrise does not "prove" that the Earth moves around the sun instead of the sun circling the Earth. However, it is good evidence supporting the earth-around-the-sun model.

There are predictable times of the year when meteors are seen more often than at others. These events are called meteor showers. Dates for some of the best meteor showers are listed in Figure 3.8.

Figure 3.8. Table of meteor showers.

NAME OF METEOR SHOWER	DATE
Omicron Draconids	August 21-23
Quadrantids	October 2
Giacobinids	October 9
Orionids	October 18-23
Taurids	October 31-November 6
Leonids	November 14-18
Geminids	December 10-13
Quadrantids	January 1-4
Kappa Cygnids	January 17
Lyrids	April 19-23
May Aquarids	May 1-6
Eta Pegasids	May 30
Alpha Cygnids	July 14
Perseids	August 10-14

PROBLEMS

1. Describe a model that would explain the regular and predictable occurrence of meteor showers.

2. Are any of the three models tested in this section similar to your model?

3. Design a program of observations that would either support or contradict the statement that meteors are seen more frequently after midnight than before midnight.

4. Test the program prepared for Problem 3.

TEACHER MATERIAL

AN ARGUMENT FOR MOTION OF THE EARTH

The changing length of days, shadows cast by the sun at different times of day and many other observations can just as easily be explained with a geocentric (earth-centered) model as with a heliocentric (sun-centered) one. Yet the geocentric notion has been replaced--and with good reason. Our purpose in not presenting the reason to students is that it may not be as "good"--from their point of view--as some writers assume. The reasons are "good" if students are familiar with the work of Newton, the principles of gravitational attraction, and the apparent motions of planets in the sky.

You could easily tell the students of Newton's work. But you could not, without devoting some time to the subject, give them first-hand evidence upon which to base a belief that the earth moves around the sun. The truth of Newton's Law of Gravitation can be discovered and understood by students; but leading them to the understanding is worthy of more time than can be allotted in this course.

Only an unusually observant student would have previously noted that the frequency of meteor fall varies between evening and morning. However, the observation is easily within the capabilities of most students and when properly analyzed, supports a model in which the earth moves around the sun.

The names of most meteor showers are related to the radiants for the showers. In the case of the Leonids, for example, most of the meteors will appear to be moving away (radiating) from the constellation Leo. In the case of the Perseids, most will appear to be radiating from a point in the vicinity of the constellation Perseus.

Problems

1. A commonly accepted model is that the particles making up a particular shower are moving in a well defined path around the sun. At regular intervals the earth passes through one of these paths. See Figure T-3.6. Other theories may be presented. Each should be judged on its own merit.

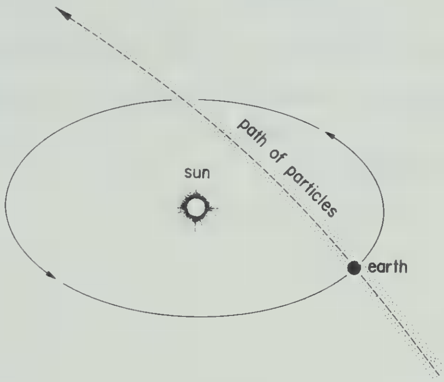


Figure T-3.6. Model of a meteor shower.

2. Answers will vary depending on the students' models. In discussing student responses you might point out that it is desirable to design models that can be tested. This is also an opportunity to emphasize that the strength of a model depends upon the number of apparently unrelated events that can be explained by its use.

3. From the list in Figure 3.8 a student might select an evening when a good show of meteors can be expected. From the listing of sunset times and sunrise times given in many local newspapers, he could establish a thirty-minute observation period shortly after dark and another shortly before dawn. During these periods he would pay close attention to the sky, keeping a record of the number of meteors seen.

The project might be shared by two or more students. Dividing the sky in such a way that each meteor is counted by only one observer may take some practice. Take into account the need for good deck-chairs from which to observe, proper clothing, an unobstructed viewpoint (away from bright lights, tall buildings, trees, etc.).

4. Whether or not the results support or refute the expected observation (a higher frequency in the pre-dawn period) students should recognize that one or two observational periods provide a rather scanty basis for generalization.

Students who like to "camp out" during the summer may be encouraged to take advantage of this pastime to make more extensive observations.

SUMMARY AND DIRECTION

Over the past several weeks you have considered a number of ideas about the Earth and the Sun. You have observed shadows and stars. In the classroom you have used a globe to help you to interpret your observations.

Single facts may be interesting. But groups of related facts often make more sense than single bits of information. Also, it is easier to remember things that are related to one another. It is our hope that the investigations and reading material have helped you to fit ideas and facts together.

But why learn these things in the first place? What difference does it make whether or not the Earth rotates?

Maybe you just happen to like to learn things about your planet. Perhaps you don't care. In either case, you are going to be asked to try to understand a possible reason for learning the sorts of things which have been presented.

This reason for learning might be called "appreciation." It is not a thing that can be tested. It is very personal. It is the way you feel about things. Here is an example:

In Investigation 2.3 you used a globe to represent a rotating planet. You saw that if the globe was turned in the proper direction, the light source would "rise" in the east. After reaching a high point, the light source would decline and then disappear in the west.

Perhaps you said to yourself, "That's something to remember. If the Earth is turning in this direction, it accounts for the movement of the sun across the sky. I'd better remember that. It might answer a test question." But there are other good reasons for remembering things.

You <u>won't</u> be tested on whether or not you learn from the activities suggested below. You won't even be tested on whether or not you try.

Sit alone and watch a sunset. (Caution: Avoid looking directly at the sun, even with sun glasses.) As the sun goes

down, try to think of the distant, western horizon rising. Think to yourself, "The sun is not dropping. The earth rolls and carries me away from it."

Or watch as the sun comes up. Think, "That happens because this mighty Earth, with me upon it, turns silently in space."

If you see a meteor in the morning sky, think, "Yes it was falling toward Earth. But also the earth ran into it while moving along through space." If you see a meteor in the evening sky, think, "What a fast meteor to have overtaken us!"

Looking through tree leaves or power lines, watch the stars move slowly. Know that the lines or leaves are moving.

Stare at a shadow long enough to see it creep across the pavement. The shadow is stationary and the Earth rolls beneath it.

Perhaps among such moments of new awareness you will find a reason for Earth Science.

TEACHER MATERIAL

Section Four:

Where You Are

PREVIEW

In Section One of the course students became aware of the problem of describing a specific location on a globe in terms which could be understood by others. The general solution is to establish a reference system and then describe a particular location in terms of this system.

In Section Two students obtained information from gnomons, interpreted with the aid of indoor gnomons, which indicated that they were located between pole and equator of the earth. Section Four returns to this question of location with a description of the system of longitude and latitude which is commonly used for reference and proceeds with refinement of earlier estimates of location.

Investigation 4.1 describes the astrolabe, a simple instrument which can be used to measure latitude and to determine heights of objects.

Determination of longitude is more complex than finding latitude. Necessary background material related to time is presented in text form. This is followed by Investigation 4.2, in which students use gnomon records to determine their longitude.

Section Four:

Where You Are

ESTABLISHING A REFERENCE SYSTEM

Earlier in the course you were presented with the problem of telling someone "where you are." Later you found ways to establish models describing where the earth is in relation to the sun and some other visible stars. You can also describe a location on earth with reference to the north and south poles and the equator. But to describe the location of any point on earth more precisely, a more complete reference system is needed. A place on the earth is often located by stating its longitude and latitude. Using the longitude-latitude reference system allows us to describe locations on the earth quite exactly.

Latitude

In Figure 4.1 a section of the globe has been removed so that you can see how angles are measured at its center. The equator circles the globe midway between the poles. The equator has a latitude of 0° (zero) and is used as a reference line for describing latitude. Line A extends from the earth's center to the equator. Suppose you used a protractor to draw Line B 20° above the first line. Line B would reach the surface of the earth at a latitude of 20°. If through this

point you drew a circle parallel to the equator, any point on the line would be 20° north of the equator, or simply: latitude 20°N.

Of course a circle of latitude 20° could also be drawn south of the equator. This latitude line is called latitude 20°S.

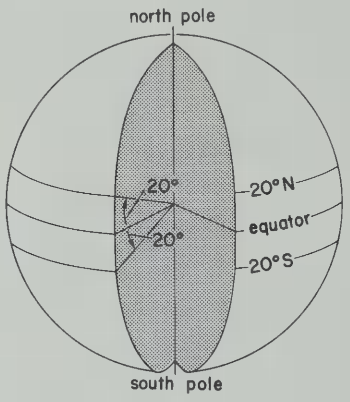


Figure 4.1.

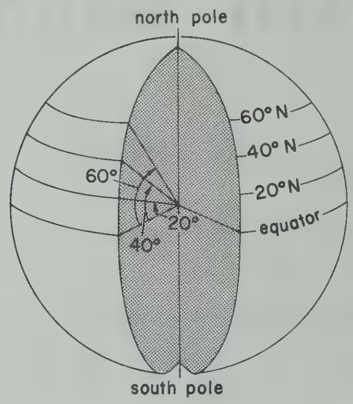


Figure 4.2.

In Figure 4.2 angles of 20°N, 40°N, and 60°N have been laid out and the corresponding circles of latitude added.

PROBLEMS

1. What is the latitude of the North Pole?

2. Do two circles of latitude ever touch?

3. On the surface of the earth, it is about 6,200 miles from the equator to the north or south pole. How many miles separate two points that are 1° of latitude apart?

4. Refer to Figure 4.3. What is the latitude of:

Madrid	Kiev
Dakar	Baghdad
Capetown	Addis Ababa
Bombay	Tananarive

Figure 4.3. The circles of latitude are, from top to bottom, 40°N, 20°N, 0°, 20°S.

Longitude

In setting up a system of latitude, you used the equator as the starting point. Longitude is measured east and west from a line of 0° longitude.

The line of 0° longitude is a half circle that extends from the North Pole through Greenwich (gren itch), England, to the South Pole. Any other pole-to-pole line could have been selected, but the English were pioneers in modern map-making and astronomy. A line of longitude is often called a meridian, (mur id ee en), and the meridian through Greenwich is known as the prime (or zero) meridian.

To lay out a certain meridian, you start somewhat as you did in setting up lines of latitude. In Figure 4.4 an angle 20° to the west of the zero meridian has been laid out. Notice that this meridian, like the zero meridian, passes from pole to pole. Any point on this meridian is said to be at longitude 20°W. Figure 4.5 shows three meridians, 0, 20°W and 20°E.

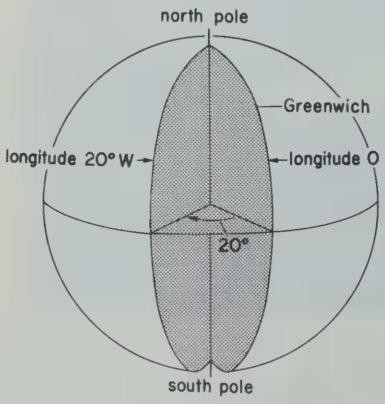


Figure 4.4.

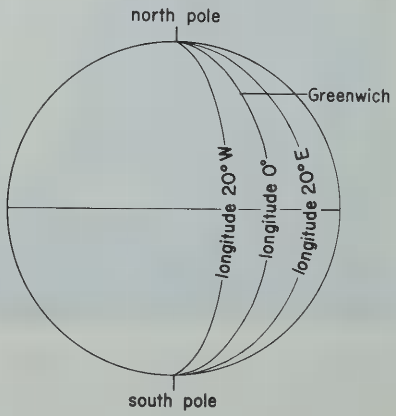


Figure 4.5.

The distance between two lines of latitude is always the same. This is <u>not</u> the case with lines of longitude. Lines of longitude are most widely separated at the equator. The distance between them decreases as they extend north or south from the equator.

PROBLEMS

1. At the equator the circumference of the earth is about 25,000 miles. What is the distance in miles between two meridians that are one degree apart?

2. What is the distance between the same two meridians at the North Pole?

3. The greatest longitude west of Greenwich is expressed as longitude 180°W. Suppose a traveler went from longitude 0° westward to longitude 180°W and then continued in the same direction for another ten degrees. What would be the longitude of his position?

4. Can any two points have exactly the same longitude and the same latitude?

TEACHER MATERIAL

ESTABLISHING A REFERENCE SYSTEM

With a little practice, students should be able to measure the longitude and latitude of locations on a globe. A large world globe should be useful in illustrating the systems. In Investigations 4.1 and 4.2 students will be asked to find the longitude and latitude of their location. Avoid specific consideration of the longitude and latitude of your location at this time.

Latitude

PROBLEMS

1. The North Pole is located at 90°N.

2. Circles of latitude never touch. For this reason they are often referred to as parallels.

3. 6,200 miles (distance from the equator to either pole) divided by 90° = 69 miles per degree.

4. Madrid -- 40°N; Kiev -- 50°N
Dakar -- 15°N; Baghdad -- 33°N
Capetown -- 34°S; Addis Ababa -- 9°N
Bombay -- 19°N; Tananarive -- 18°S

We have intentionally selected a portion of the earth that does not include North America. Thus, unless a student has taken the initiative to find his own latitude (from a globe or atlas), he will not be biased when determining his own latitude in a later investigation.

Longitude

PROBLEMS

1. The distance is the same as between two adjacent lines of latitude, or about 69 miles per degree and may be found by dividing the circumference at the equator by 360°.

2. There is no separation; all meridians meet at that point.

3. Once the traveler passed the 180th meridian he would be approaching Greenwich. His longitude would be 170°E.

4. No two points can have exactly the same longitude and latitude. This is one of the main considerations in establishing a system for describing locations.

NOTE: If you intend having students plot locations of earthquake epicenters as reported by ESSA, you may wish to introduce the exercise as "practice in longitude and latitude." A mercator projection map of the world can be pinned to a bulletin board and epicenter locations marked with small dots of a marking pen. Besides gaining practice in working with geographical coordinates, students should notice very soon that the epicenter locations form a pattern. The dots will be clustered along margins of the Pacific Ocean and across the Himalaya to the Mediterranean. Encourage speculation on the implications of the pattern, but withhold definite statements concerning it until students have considered Section Ten of the course. The map can be left up or--if interest wanes--stored for review during the selections on earthquakes and sea-floor spreading, in which the significance of the pattern is brought out.

INVESTIGATION 4.1: Determining Your Latitude

In previous material you have learned the meaning of latitude. You are now ready to measure the latitude of your location on earth.

Materials

Cardboard 20cm x 30cm
String
Protractor
Weight
Scissors
Stapler
Metric ruler

If you wish to tell someone the location of a star, you must give him a compass direction (azimuth, refer to Investigation 1.2) and the altitude (angle above the horizon) of your line of sight. The next procedures may help you to understand that the altitude of Polaris has a special significance.

Procedures

A. Copy Figure 4.6 in your notebook. Look at Figure 4.7. In this diagram horizontal lines and lines of sight to Polaris are drawn for four observers. Use your protractor to measure the angle near the center of the earth that will describe the latitude of each observer. Enter the latitude of each observer in the first column of Figure 4.6 in your notebook.

OBSERVER	LATITUDE	ALTITUDE OF POLARIS
1		
2		
3		
4		

Figure 4.6.

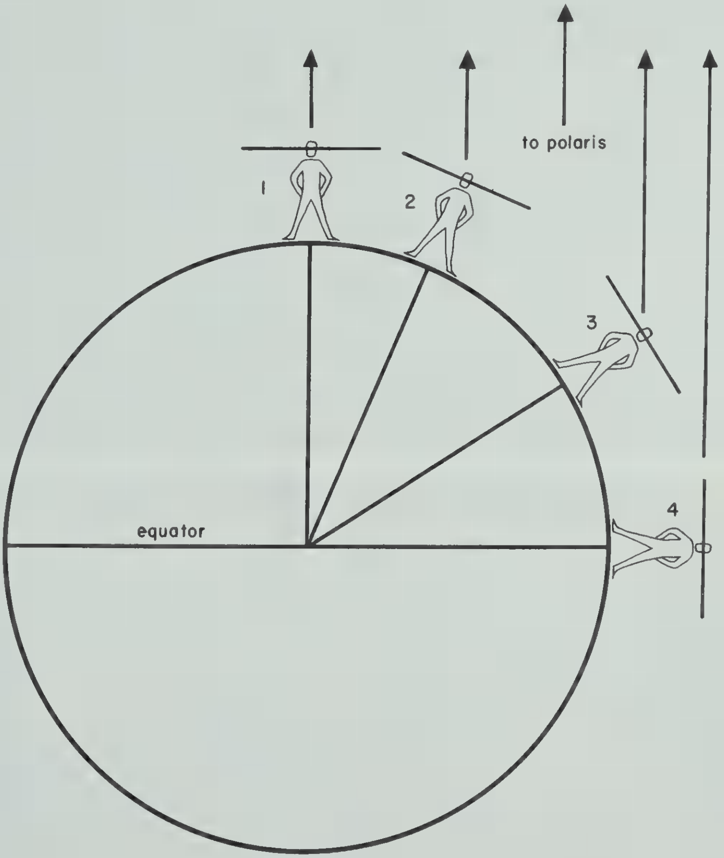


Figure 4.7. Diagram for Procedures A and B.

B. Use your protractor to measure the angle between a horizontal line and the line of sight to Polaris for each of the four observers. Enter these angles in the second column of your copy of Figure 4.6.

Interpretations

1. How do the angles in the second column compare with the angles in the first column?

Procedures (continued)

C. In this procdure you will construct an insturment called an astrolabe (as tro layb). It can be used to measure vertical angles.

Using a straight edge, draw a line across the cardboard. Near the middle of the line make an index mark with a pencil (Figure 4.8a).

Use scissors to cut a triangular notch at each end of the line as shown. The notches should be about 1.0cm deep.

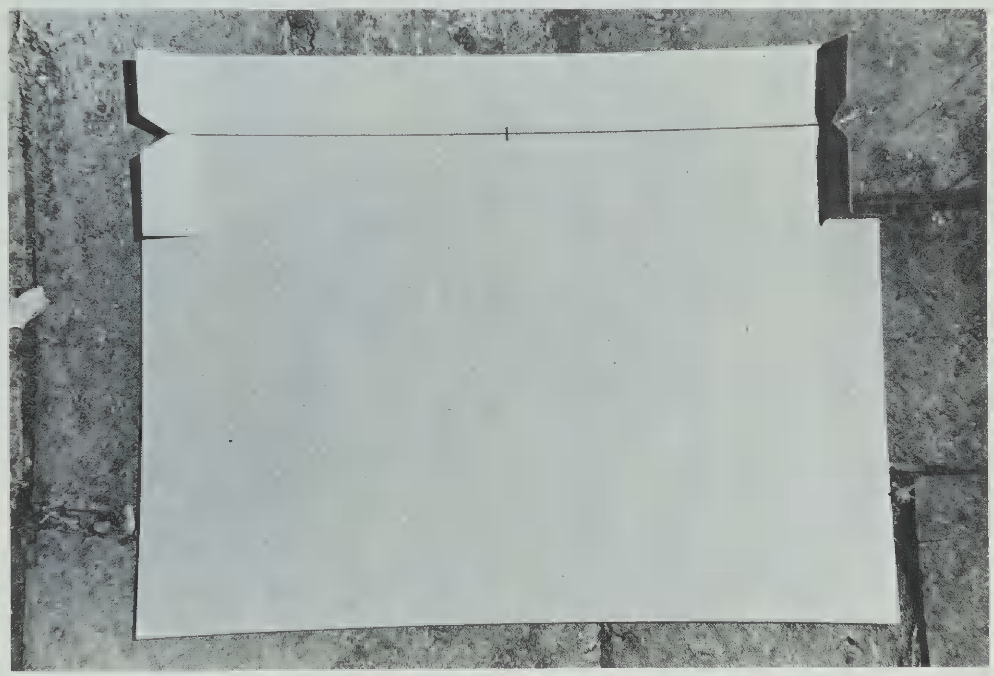
Ten cm from each of the upper corners of the cardboard make a cut two cm long. Fold the cardboard as shown.

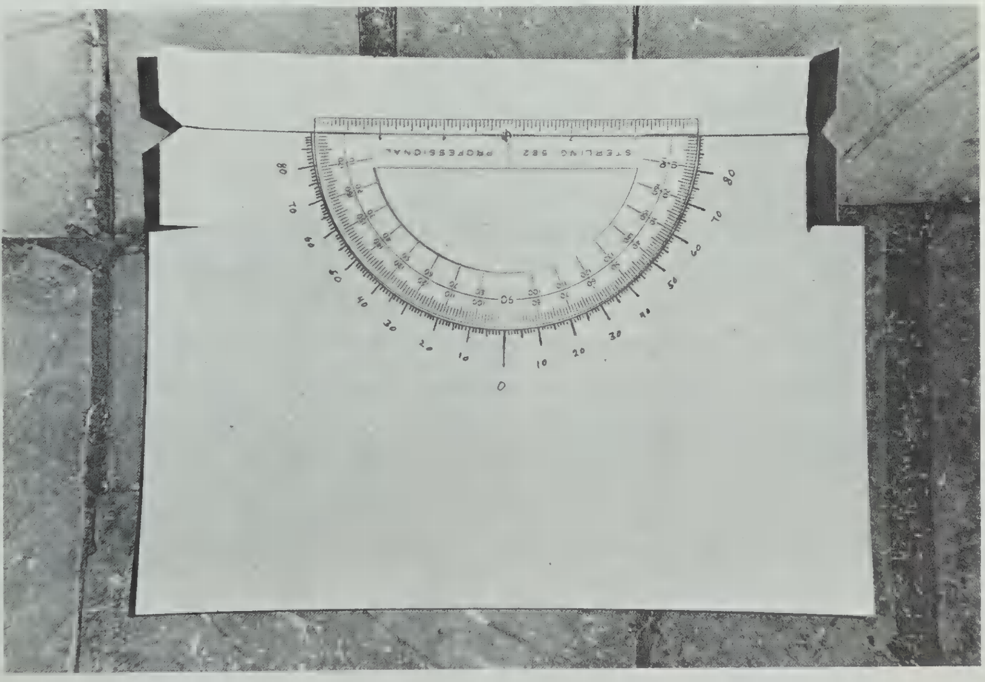
Place a protractor on the cardboard as shown in Figure 4.8b, and carefully mark off degrees. Make each five-degree and ten-degree mark as shown in Figure 4.8c. (Do not copy the degree marks shown on the original protractor. Mark the degrees as illustrated.)

Place the string over the index mark. Use a staple to fasten the string at the index mark. Use a second staple for extra strength. Tie the weight low enough on the string to let it swing free of the instrument.

The astrolabe is completed and can be used to measure the altitudes of stars.

Figures 4.8a, 4.8b.





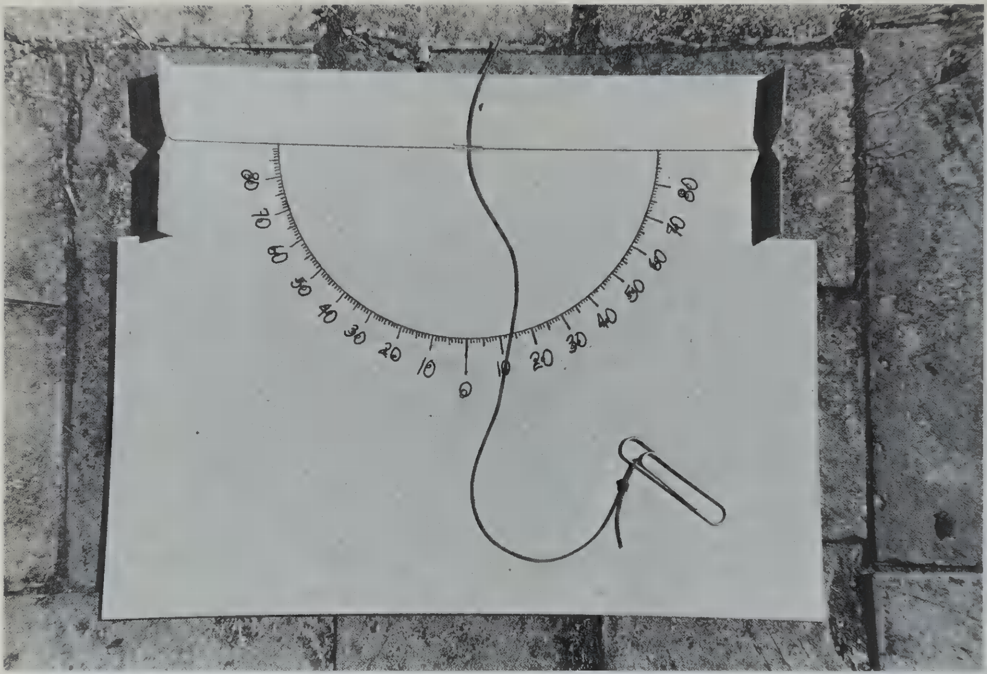


Figure 4.8c.

NOTE: The following procedures will have to be done at home in the evening.

D. To measure the altitude (angle up from the horizon) of Polaris hold the astrolabe as shown in Figure 4.9. In the evening, face Polaris and raise the far end of the astrolabe until you sight Polaris through the notches. When you do, press the string against the cardboard, and read the angle at which it crossed the scale. This angle is the altitude of Polaris.

Figure 4.9. Using an astrolabe.

E. Take your astrolabe home tonight and measure your latitude.

Interpretations

2. What is your measurement for the latitude of your home?

3. What is the average of the values obtained by your class?

4. What latitude for your location is given on maps?

INVESTIGATION 4.1: Determining Your Latitude

Materials

The astrolabes prepared in this investigation can also be used in Investigation 5.3.

Procedures

A. See Figure T-4.1 below.

OBSERVER	LATITUDE	ALTITUDE OF POLARIS
1	90	90
2	65	65
3	30	30
4	0	0

Figure T-4.1.

B. See Figure T-4.2. Data are shown in Figure T-4.1.

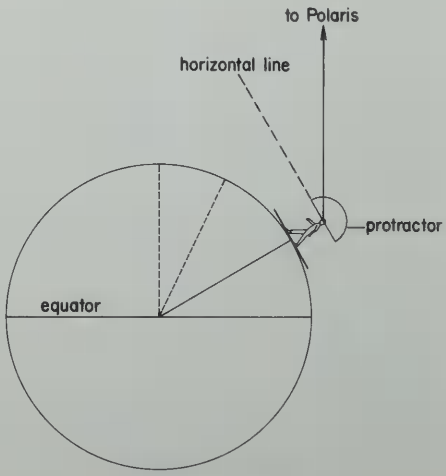


Figure T-4.2. One method for measuring the altitude of Polaris.

Interpretations

1. The angles are equal. The altitude of Polaris is equal to the latitude. Within a degree or two the values recorded in the two columns should agree. It would be better to allow students a little leeway here than to make them feel that they had better "fudge" answers in order to get them "right."

Procedures (continued)

C. Make sure the string is attached to the cardboard at the center of the reference line and not above or below it. You may allow students to attach a protractor directly (with transparent tape) to the cardboard to save time. This however may result in loss of the protractor, and it "ties up" a number of them which may be needed for following investigations. Also students will have to count the number of degrees as if $90^{\circ} = 0$.

D.-E. No comment.

Interpretations

2. Answers will vary depending upon your location and the care students exercise in the activity. It might be well to talk to students ahead of time about the amount of accuracy expected. Some students would probably be disappointed if they missed the "correct" latitude by one degree. Actually, coming within five degrees is satisfactory. See Figure T-4.3 for latitudes of locations in the United States and Canada.

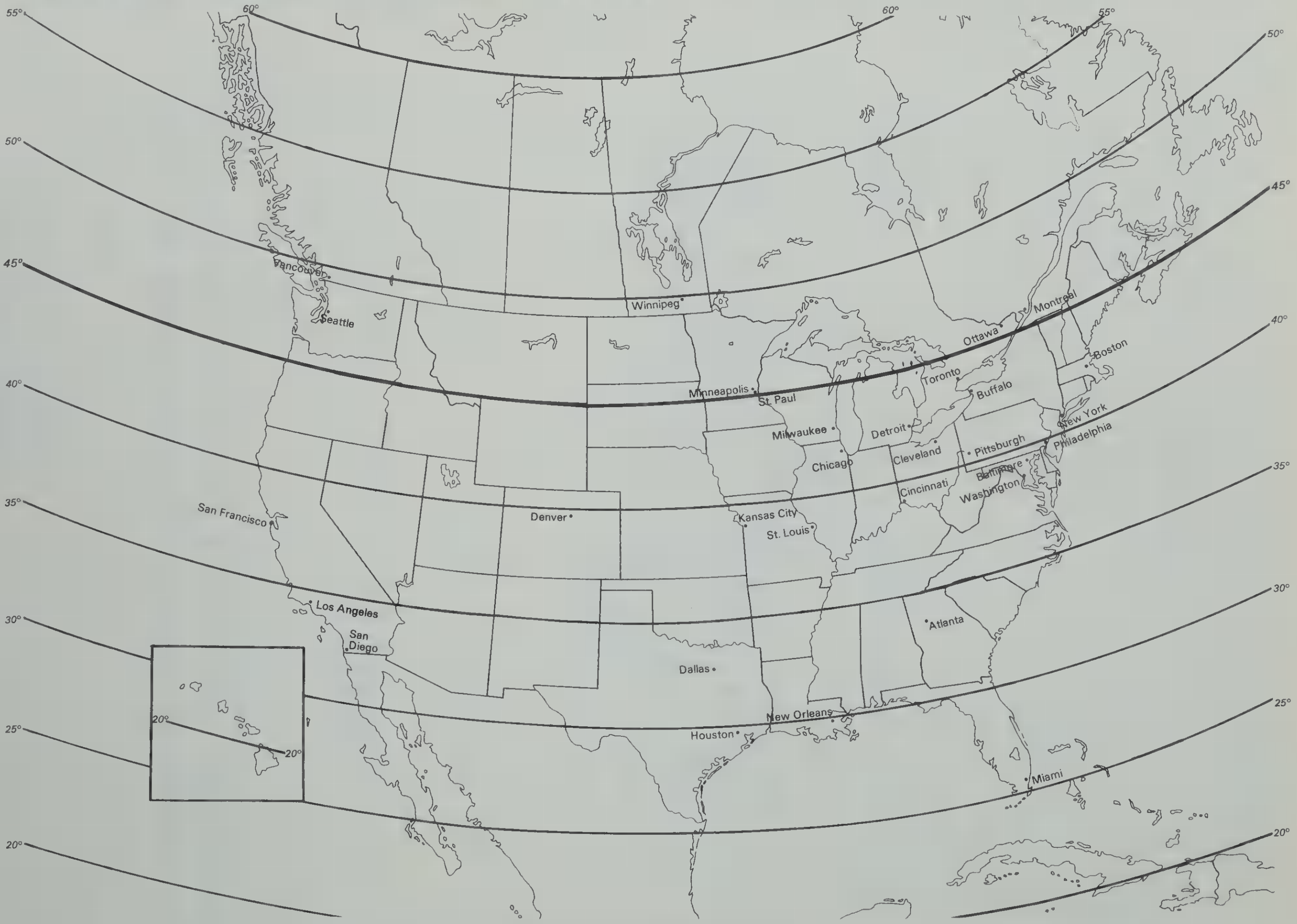


Figure T-4.3. Map of the United States and Canada, showing lines of latitude.

3. The benefit of averaging results should be pointed out to students if you discuss this part of the investigation. For every student who made an error in one direction there is likely to be another student who made a compensating error.

4. The answer depends on your location. Polaris is not located exactly at the celestial pole but moves around it at an angle of about one degree. No allowance is made for this, and you should not expect the answers to come closer than two degrees to the map value, even for the averaged result.

LONGITUDE AND TIME ZONES

As the Earth rotates the sun appears to move across the sky. At one instant of time in each day the sun will be directly south of you. This instant is called noon or sun-noon. Before this time the sun will be to the east; after this time it will be to the west.

Everyone who lives along one meridian of longitude will experience noon at exactly the same instant. Those who are farther to the east will experience noon earlier; those to the west will experience noon later.

Our clocks are set so that noon will occur at <u>about</u> 12 o'clock. But if the people in <u>each</u> location set their clocks to read 12 o'clock when the sun passed to the south of them, there would be a great deal of confusion. When it was 12 o'clock in your area, neighboring towns to the east and west would have their clocks and watches set for other times. It would be very difficult to arrive at any place at the correct time. And if your watch ran down, you could not use a time signal from the radio to re-set it.

When North America was first being settled, each local area had its own time. Persons who traveled had the most difficulty. Railroads kept their own time and ignored local systems. The following was printed in the <u>Chicago Daily News</u>, September 29, 1948.

> "Before 1883 there were nearly 100 different time zones in the United States. It wasn't until November 18 of that year that . . . a system of standard time was adopted here and in Canada. Before then there was nothing but local or 'solar' time . . . The Pennsylvania Railroad in the East used Philadelphia time, which was five minutes slower than New York

> time and five minutes faster than Baltimore time. The Baltimore and Ohio used Baltimore time for trains running out of Baltimore, Columbus time for Ohio, Vincennes (Indiana) time for those going out of Cincinnati . . . When it was noon in Chicago, it was 12:31 in Pittsburgh; 12:24 in Cleveland; 12:17 in Toledo; 12:13 in Cincinnati; 12:09 in Louisville; 12:07 in Indianapolis; 11:50 in St. Louis; 11:48 in Dubuque; 11:39 in St. Paul; and 11:27 in Omaha. There were 27 local time zones in Michigan alone . . . A person traveling from Eastport, Maine, to San Francisco, if he wanted always to have the right railroad time and get off at the right place, had to twist the hands of his watch 20 times en route."

Since 1883 the system of "standard" time has been used in North America. Time zones run north and south on the globe. Within a time zone all clocks are set alike. People who travel change their timepieces only when they enter a different time zone.

The width of time zones is a result of our system of time and longitude. The earth completes one rotation every 24 hours. From east to west it is divided into 360 meridians, or degrees. Therefore, in one hour the earth rotates through 15° ($360^{\circ} \div 24$). The sun is 15° farther west each hour, and time zones are 15° wide. Thus noon in the center of one time zones is one hour later than noon in the center of the next zone to the east. Longitude at the approximate center of each time zone in North America is listed in Figure 4.10 and shown on the map (Figure 4.11).

Atlantic Standard Time	60°
Eastern Standard Time	75°
Central Standard Time	90°
Mountain Standard Time	105°
Pacific Standard Time	120°
Yukon Standard Time	135°
Alaska-Hawaii Standard Time	150°
Bering Standard Time	165°

Figure 4.10. Longitudes of the central meridians of some time zones.

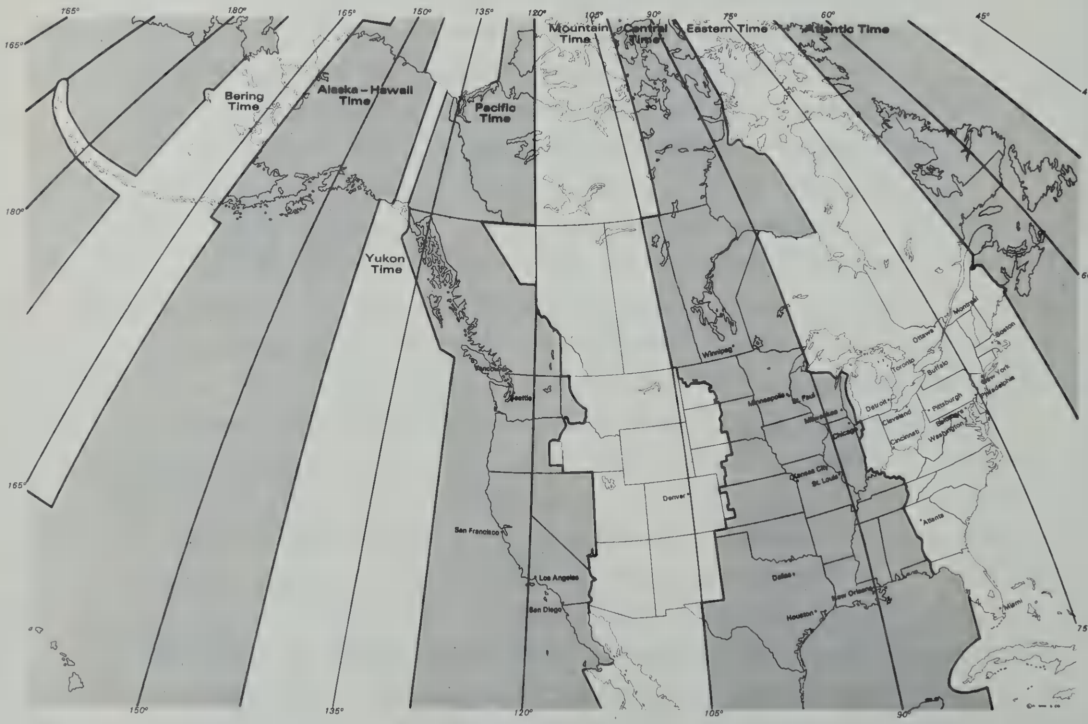


Figure 4.11. Time zones in North America.

VARYING NOON

It is fairly easy to see that two people located on different meridians will experience sun-noon at different clock times. One might think that on a given meridian, sun-noon should occur at the same clock time day after day--but this not always is the case. Careful observations have shown that from day to day, sun-noon may occur at different clock times on the same meridian! For example, along the central meridian of the Mountain Time zone (105°W) on the first of September, sun-noon occurs at 12:00 o'clock. On September 20th, however, sun-noon occurs at 12:05 o'clock. On October 20th it occurs at 12:14.

The reason sun-noon does not occur at regular 24-hour intervals is because the earth moves around the sun a little slower in summer than in the winter. This effect is described in "Changing Speed." Figure 4.12 shows the time corrections that allow for changes in speed.

TIME CORRECTION IN MINUTES

Date of Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	-4	-13	-13	-5	+3	+3	-2	-6	0	+8	+15	+14
10	-7	-14	-10	-2	+4	+1	-4	-5	+2	+12	+15	+10
20	-11	-14	-8	+1	+4	0	-6	-3	+5	+14	+15	+7

Figure 4.12. Table of time corrections. Plus (+) means add the number of minutes to clock time. Minus (-) means subtract the amount from clock time.

CHANGING SPEED (OPTIONAL)

How much time passes from noon of one day till noon the next? About 24 hours, of course. But notice the "about." An accurate clock will show that from sun-noon of one day till sun-noon the next is not exactly 24 hours by the clock! During certain seasons of the year the sun is lagging behind the clock; at other times it catches up and gets ahead of the clock. This suggests that the Earth does not travel at a constant speed around the sun.

Look at Figure 4.13. This diagram shows a planet moving around the sun in a circular orbit at a steady speed.

It takes the same length of time for the planet to move from A to B as from B to C, etc. Suppose a clock is set to tick off 24 hours while the planet moves from A to B. A person at point X on the planet rides all the way around as the planet turns (from X to X^1) during this 24 hours. Twenty-four hours of clock time will pass between noon of one day and noon of the next.

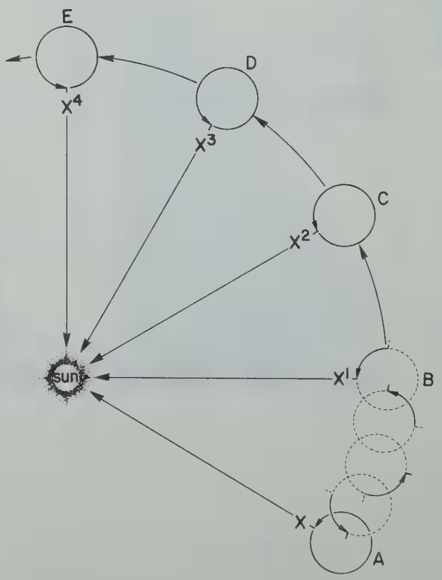


Figure 4.13.

Twenty-four hours later the planet will be at C, with the person at X^2. Again he will observe the sun directly overhead.

Notice that the planet has rotated a little <u>more</u> than 360° from noon to noon. In the example (Figure 4.13), the planet rotates 390° in 24 hours. Use a protractor to check this if you wish.

The same amount of time goes by and the planet moves the same distance from C to D, D to E, and so on. The planet has a very short year (only 12 days), but this does not affect the argument.

Now imagine that the observer's planet moves more rapidly around the sun, but rotates at the same rate--390° in 24 hours (Figure 4.14). Instead of moving from D to E in 24 hours, it moves clear over to F. Here, 390° of rotation is not enough to bring the sun directly overhead at X^4. The observer has two choices: 1) He can slow his clock down so that 24 hours of the new, longer "hours" will bring the sun overhead. 2) He can let his clock run at the same speed and say that sun-noon is a little late.

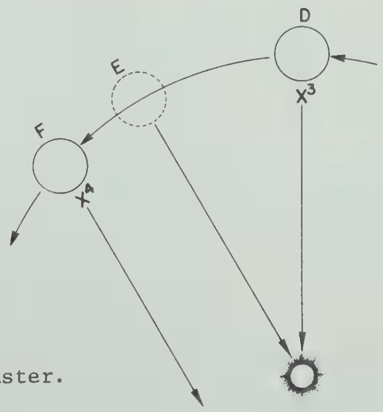


Figure 4.14. A planet moving faster.

Here on Earth we have a similar problem. In winter the earth moves a little more rapidly around the sun than it does in summer. This is because the earth's orbit is not a perfect circle, but an ellipse (Figure 4.15).

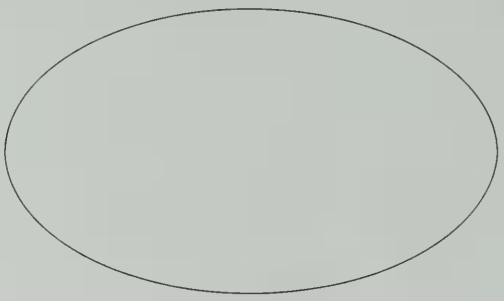


Figure 4.15. An ellipse, or regular oval.

On Earth, it is customary to let clocks run at a steady speed all year round. As a result, sun-noon may differ from clock-noon. The greatest difference is fifteen minutes, occurring in February and again in November.

In your notebook, look at your earlier gnomon record (Investigation 2.1). Did sun-noon occur just at 12 o'clock? If not, part of the reason may be the result of the changing speed of the earth in orbit. The rest of the reason results from the fact that relatively few people live on one of the time zone meridians.

PROBLEM

Imagine a planet that is stationary but spinning on its axis. Draw a diagram showing the sun moving around the planet, and show how the length of day would change if the sun speeds up or slows down.

TEACHER MATERIAL

LONGITUDE AND TIME ZONES

No comment.

VARYING NOON

Some students may find it difficult to follow the geometric analysis. Nevertheless, they should understand that the earth does speed up and slow down as it moves around the sun. The reading material should provide the background for Procedure B and Interpretations 2 through 4 of Investigation 4.2. For students to find their longitude, corrections must be made for the cumulative effect of these changes in speed.

CHANGING SPEED (OPTIONAL)

PROBLEM

One solution is shown in Figure T-4.4. The planet is stationary, but spinning. In the time it takes for the planet to spin through 390° (one complete rotation plus 30°) its sun has moved from position A to B. An observer on the planet at X would have rotated completely around once and then to X^{1}. This would be just enough so that the observer would again be experiencing noon.

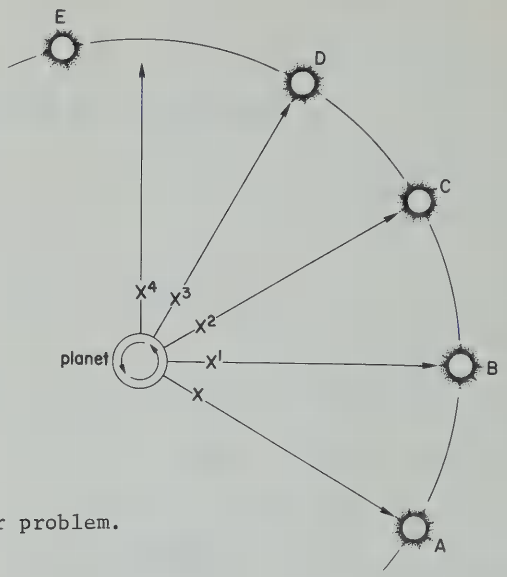


Figure T-4.4. Diagram for problem.

In Figure T-4.4, Position E shows what happens if the sun orbits more rapidly. In the time required for the planet to spin through 390° (from X^3 to X^4) the star has speeded up and moved from D to E. Thus it is not overhead 24 hours later, when the observer is at X^4. The observer will notice that sun-noon is a little late on this day. The opposite effect occurs if the sun slows down; sun-noon will then be a little early on succeeding days.

INVESTIGATION 4.2: Finding Your Longitude

In the last investigation you made a measurement of latitude at your location. Now you will measure your longitude. This is somewhat more complicated than finding latitude. Historically, navigators knew how to find latitude many years before a system was developed for determining longitude.

Materials (per team)

- Gnomon board
- Protractor
- Drafting compass
- Centimeter rule
- Clock or watch

<u>Procedures</u>

A. Make a new gnomon record following the procedures described in Investigation 2.1. Make all observations with care, especially those regarding time.

Interpretations

1. At what clock time did noon occur on your meridian (what time was the sun directly south of you)? See Investigation 2.2 for details of analyzing your gnomon record.

<u>Procedures</u> (continued)

B. Find the correction to be applied to the time you determined for Interpretation 1. (See Figure 4.12)

Interpretations

2. What is the proper correction, in minutes, for the date of the gnomon record?

3. Should this correction be added to or subtracted from the clock time of Interpretation 1?

4. At what corrected time did the sun pass over your meridian?

5. Remember that the sun seems to move at a rate of one degree every four minutes. What is the difference, in minutes, when 12:00 o'clock is subtracted from your response to Interpretation 4?

6. How many degrees of longitude separate your meridian from the central meridian of your time zone?

7. The direction of the apparent motion of the sun is from east to west. If the corrected time (Interpretation 4) at which the sun passed your meridian is before 12:00 o'clock, you are east of the time zone (central) meridian. If the sun passed your meridian after 12:00, you are west of the central meridian. Determine whether your location is east or west of the central meridian of your time zone.

9. In which time zone are you located? (Refer to Figure 4.11.)

10. What is your longitude?

PROBLEM

Check the date on which you first performed the investigation with the outdoor gnomon. Use Figure 4.12 to find the time correction needed for that date. Repeat the steps of Investigation 4.2 using the data from your first gnomon trial. Compare the longitudes found on those two dates.

INVESTIGATION 4.2: Finding Your Longitude

Materials

No comment.

Procedures

A. If you do not wish to have the gnomons out all day, at least try to have them out during the period 11:00 a.m. to 1:00 p.m. standard time. This will give sufficient data from which to determine longitude. Leaving the devices out longer (say from 9:00 a.m. till 3:00 p.m.) will produce records showing more apparent differences from earlier records.

Interpretations

1. Each team can make its own observations. Since there is a "right" answer for this investigation (the longitude as determined from a map of your area), teams may enjoy the competition. On the other hand, since the procedures involved in working through the data are rather involved, you may wish to find an average value for the clock time of sun-noon and have the entire class work through the procedures together, using the same figures.

Procedures (continued)

B. No comment.

Interpretations

2. Answers will vary.

Sample correction: A record made on October 15 showed the shadow line closest to the gnomon at 12:03 p.m., clock time. From the table you can see that the correction is about 13 minutes.

3. The answer depends on when the investigation is done.

4. Answers will vary. For the sample, the sign of the correction is "+" so 12:03 plus :13 equals 12:16 p.m., the corrected time at which the sun passed over the meridian.

5. Answers will depend on the time of year and your location. For the sample correction, 12:16 - 12:00 = 16 minutes.

6. Answers will depend on your location. Every four minutes before or after 12 o'clock equals one degree of longitude away from the central meridian. For the example, 16 minutes
4 minutes per degree = 4°.

7. Answers will depend on your location. For the example, the correction was positive, and the location is therefore west of the central meridian of the time zone.

8.-9. The answer depends on your location.

10. The answer depends on your location. For the sample data, assume you are in the Eastern Time Zone. Therefore, 75°W Longitude + 4° = 79°W.

Problem

This may be used as an optional activity if time is short. If the problem is assigned, provide students with the time correction, and tell them whether to add or subtract. The time zone and its meridian and the longitude of your location should not be different.

The accuracy of the longitude found can be checked against a map. A degree or so of error is not unlikely, given this equipment. At Lat 30°N a degree corresponds to 61 miles; at Lat 35°N, 55 miles; and at Lat 40°N, 51 miles.

Section Five:

Describing Things with Numbers

PREVIEW

In Investigations 1.1 and 1.2 students became familiar with protractors and angular measurement in order to deal with the concepts involved in the subsequent sections.

Similarly, Section Five provides students with concepts and techniques which will be required in later parts of the course. Although measurement is an interesting subject in itself, its study is not central to earth science, and this section should be treated as briefly as is consistent with student background.

The first selection in the section, Describing Things With Numbers, defines measurement and suggests the need for it. This is followed by an investigation in which distances are estimated and one in which distances are measured. Following direct measurement of distances, students are introduced to triangulation, a technique by which distances may be measured indirectly. Volume is considered next and, finally, density.

Conversions between metric and English systems should not be unduly emphasized. A student who can indicate with his hands the approximate length of a meter will be better equipped for later parts of the course than will one who can quote that "a meter is equal to 39.37 inches" without having a feel for the length of either unit.

Section Five:

Describing Things with Numbers

Words such as "large" and "small," "hot" and "cold," occur quite often in our speech and writing. This may be because the words are so very useful. It may also be due to the fact that they are very easy to apply. Consider the following conversation:

"Was it a large dog or a small one?"

"It was a big dog!"

The person describing the animal didn't need a measuring stick to decide that the dog was big. The person who asked the question found out that the animal was not a dachshund or chihauhau. In size it was probably more like a collie or a shepherd.

But descriptions such as "big" and "small" can have shortcomings. Their meanings may depend not only upon the experience of the person who uses the word, but also upon the particular type of object being described.

To avoid confusion over words such as "warm" and "cold," or "big" and "small," scientists often describe things with numbers. Such descriptions are called measurements. In this section you will find out something about the need for measurements. You will also find out ways in which certain types of measurements are made.

PROBLEMS FOR DISCUSSION

1. In each of the following short conversations, two people are disagreeing about a description. For each conversation try to suggest a reason for the confusion. Try also to state whether the disagreement is due to different past <u>experience</u> of the people or whether it is due to the <u>object</u> of the description.

I "Gee, is it always this cold around here?"
"Cold? This is what I'd call a really warm day."

II "It was absolutely <u>huge</u>. It must have weighed over a pound!"
"I wouldn't call that very heavy. I can lift <u>50</u> pounds easily."

III "A mile doesn't seem like a very long distance to me."
"Well, you just don't know how long a mile can be."

2. Measurement is not always desirable or necessary. Try to describe a situation in which you think a description using words such as "large" or "cold" would be better than one which required the use of measurement.

TEACHER MATERIAL

DESCRIBING THINGS WITH NUMBERS

The selection is designed to encourage speculation about the relative values of qualitative and quantitative descriptions.

PROBLEMS FOR DISCUSSION

1. I - Students may suggest that the conversation could have taken place in a town in the far north where a person from a warmer area is visiting. The disagreement is probably due to differences in experience of the speakers. Encourage alternate solutions by students.

II - The confusion here may result from the fact that the object of the description is not known. Fifty pounds is not a great weight to lift, but a one-pound ant or a one-pound diamond would be considered "large." An element of experience is also suggested. The second speaker is referring to his experience in lifting objects, but the first speaker apparently didn't have this in mind.

III - This disagreement could probably result from either of the suggested causes or a combination of both. The first speaker may be accustomed to walking in flat terrain, while the second is thinking of his experiences in rugged, mountainous country. Perhaps the first speaker is thinking of walking a mile while the second is thinking of swimming a similar distance. These would be primarily differences in experience. Or the speakers may be referring to entirely different subjects. If the first speaker is an astronomer and the second a land surveyor, their ideas concerning an error of one mile could be quite different.

2. A person rushing into a hardware store to obtain a rope to save a distressed swimmer would probably state his requirements as "strong" rather than attempting to define the required breaking strength of the cordage.

A guest at dinner, asked whether he would prefer a large or small portion, would generally do better to answer in subjective terms than to state his preference in terms of calories (food value) or weights.

INVESTIGATION 5.1: Estimating Distances

Sometimes a subjective word, such as "large," is as good as or even better than a measurement. Such words can be quickly and easily applied. Often they give all the information that is needed.

At other times a measurement, such as "32 miles," is needed.

As you may imagine, there are in-between situations. At such times, estimates may be of value. In this investigation you will practice estimating distances.

Materials

Notebook and pencil

Procedures

A. During the 1968 Summer Olympics in Mexico City, Bob Beaman set a world record in the running long jump by jumping a distance of over 29 feet. Have one member of your team place two objects on the floor so they appear to be about this distance apart. Have other members of your team check the placement by pacing off the distance.

Figure 5.1. Bob Beamon, holder of the world record in the running long jump.

B. Draw two circles on your paper. One circle should be about the size of a nickel. This circle is to represent a basketball. Around it draw a second, larger circle to represent the relative size of a basketball hoop. If a regulation basketball is nine inches in diameter, what is the diameter of a basketball hoop?

C. Compare the results of these estimates with those made by other teams.

D. Copy Figure 5.2 in your notebook. Try to guess which of the pairs of lines in Figure 5.3 are equal in length and in which pairs one line is longer than the other. Do not use a ruler or any other object--base your decision only on what you are able to see. Record your guess for each pair of lines in the chart. If you think the lines in a pair are the same length, write "same" under line A and line B. If you think one line of a pair is shorter, write "short" in one space, "long" in the other. When finished, compare your results with those of others in the class.

Pairs of Lines	Line A	Line B
I		
II		
III		
IV		
V		

Figure 5.2.

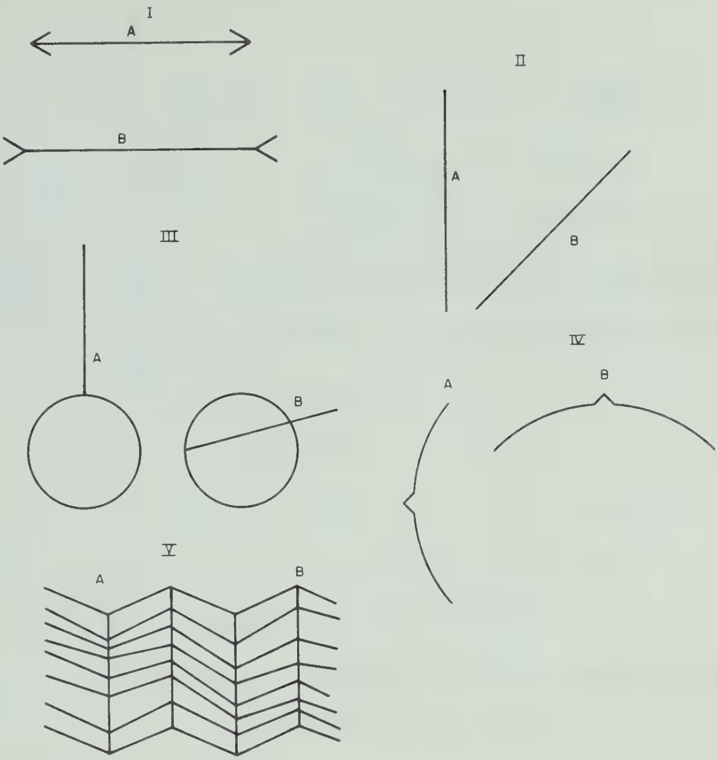


Figure 5.3.

QUESTION FOR DISCUSSION

1. Why do you think scientists prefer not to estimate distances.

INVESTIGATION 5.1: Estimating Distances

We hope students will regard this investigation as an enjoyable exercise. Actually it is much more than that, since it leads slowly but directly into accurate measurement. Also, you should point out that before the invention of standard measuring devices such as a ruler, measurements were very inaccurate. Perhaps the best time to carry out a class discussion on ancient and modern methods of measurement is after they have completed this investigation.

Materials

Students should not be allowed to use a ruler until this investigation is completed. English-metric rulers should be available for use by students at the end of the investigation and for use in Investigation 5.2.

Procedures

A. Some students may try to be "exacting" in their measurements by placing one foot directly in front of the other so that their results will be recorded in terms of the length of their feet. Others will use a "pace method," where a distance of approximately three feet is paced off. This will result in a distance expressed in yards and the figures will have to be divided by three to give the distances in feet.

Students are most likely to underestimate the 29-foot distance if the estimate is made in a small classroom. (Your classroom may not be 29 feet long.) People tend to overestimate distances outdoors. You may want to verify this by allowing some teams

to work outdoors on this procedure. Such estimates are usually biased by the surroundings.

Another bias has been introduced here. Many people are at first reluctant to admit that anyone can actually jump a measured 29 feet. A student may closely estimate 29 feet only to have others argue that no one can possibly jump that far. Even after pacing off the distance, some may be reluctant to accept the estimated distance. At this point you may want to hand out meter sticks for the students to verify their estimates.

B. Two basketballs side by side will almost fit through a basketball hoop at the same time. A regulation basketball is just over nine inches in diameter while the hoop is 18 inches in diameter.

C. You may want to discuss the topic of bias in measurement with the class at this point.

D. Student guesses are likely to vary since guessing distances here is influenced by optical illusion. The "correct" chart should be similar to Figure T-5.1.

Pairs of Lines	Line A	Line B	
I	Short (50mm)	Long (53mm)	
II	Same	Same	
III	Same	Same	
IV	Short (50mm)	Long (55mm)	measured on straight line connecting ends of arc
V	Same	Same	

Figure T-5.1.

Some students are likely to guess that both lines in I are equal because they have seen similar pairs of lines presented as "optical illusions." After student results have been compared they should be asked to check their results with a ruler. The next investigation introduces use of the metric system of distance measurement.

QUESTION FOR DISCUSSION

1. See teacher material above.

INVESTIGATION 5.2: Measuring Distance Directly

So far in your life you may have used only the English system of measurement to express lengths--feet and inches. A more widely used system is called the metric system. The metric system is used by nearly all scientists and in nearly all countries of the earth. For the present you will concern yourself with but one phase of the metric system--that involving length.

The basic unit of length in the metric system is the meter (abbreviated m). The meter is divided into 100 equal parts called centimeters (abbreviated cm). It may help you to remember this if you think of a dollar as representing a meter. There are 100 cents in a dollar and 100 centimeters in a meter.

Centimeters are divided up into still smaller units called millimeters (abbreviated mm). There are 10mm in a centimeter. How many millimeters are in one meter?

(Answer: $\frac{10\text{mm}}{\text{cm}} \times \frac{100\text{cm}}{\text{meter}} = 1000\text{mm/meter}$)

Examine Figures 5.4 and 5.5 below. They show the relationship between the three units on a meter stick.

Figure 5.4

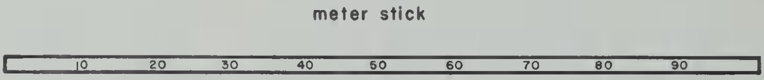
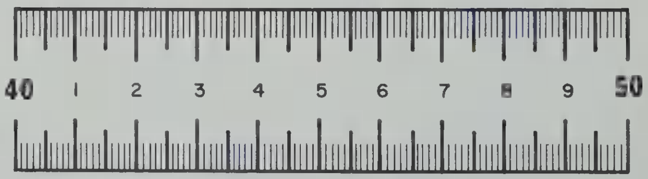


Figure 5.5.



Materials

Meter stick (or 30cm ruler)

Procedures

A. Using the meter stick measure the length in millimeters of each line in Figure 5.6. Record each measurement in your notebook.

Figure 5.6.

B. In the English system, measurements are commonly given in mixed units such as, "He is five feet, ten inches tall." Such is not the case in the metric system. A line 57mm long, for instance, would not be described as "five cm, seven mm long." Instead, its length would be recorded simply as 57mm or, 5.7cm (pronounced, "five and seven tenths centimeters, or, five point seven centimeters). Thus, each millimeter can be expressed as one tenth (0.1) of a centimeter. Measure the length in cm of each line in Figure 5.6. Record your measurements in your notebook.

C. Measure and record the length of your classroom in meters.

D. Measure and record the length of this page in cm.

E. Measure and record your height in centimeters.

Interpretations

1. Why do you think most scientists use the metric system of measurement?

ADDITIONAL ACTIVITY

1. Write a short report about world's records in sports events. List the records in both English and metric units.

TEACHER MATERIAL

INVESTIGATION 5.2: Measuring Distance Directly

Measurement and use of the metric system are skills that are mastered only by practice and repeated use. You should not feel that students will "know" the metric system after completion of this investigation--it is only introductory. Your insistence on student use of metric system for most measurements will help increase their competence to a working level.

Materials

Meter sticks are preferred if available.

<u>Procedures</u>

A. Line X = 20mm
   Line Y = 45mm
   Line Z = 63mm

B. Line X = 2.0cm
   Line Y = 4.5cm
   Line Z = 6.3cm

C. Answers will vary.

D. The page is 27.9cm long.

E. Answers will vary.

Interpretations

1. Use of a common measurement system reduces error and effort in conversions from one system to another. Also, computations are "cleaner" in metric values because clumsy fractions and mixed units are eliminated.

ADDITIONAL ACTIVITY

A recent world almanac is a complete source for such records.

INVESTIGATION 5.3: Measuring Distance Indirectly

When short distances are measured on the ground, it is possible to use rulers or tape measures. Obviously, in measuring very great distances, this is not practical. In this investigation, you will see how distance measurements can be made indirectly.

Materials (per team)

Protractor
Index cards, 2
Meter stick
Metric ruler
Tape
Unruled paper

Procedures

A. With both eyes open look at a fixed object on the far side of the room. Hold one hand up, fingers together, palm toward your face. Move your hand back and forth to block the view from first one eye and then the other. Record your observations.

B. Now hold a pencil at arm's length in front of you. Continue to look at the distant object. Notice any changes in apparent position of the pencil as you block vision of first one eye and then the other. See Figure 5.7. Bring the pencil closer to your face. Again block vision of first one eye and then the other. Record your observations.

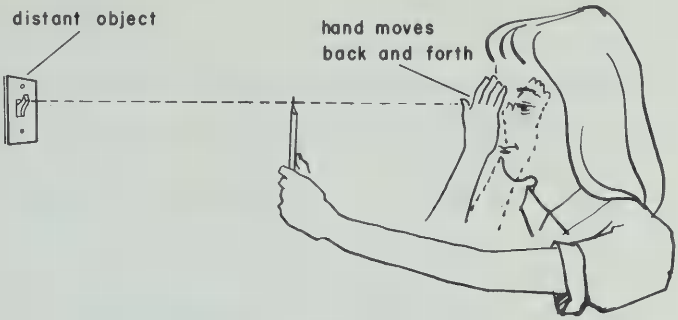


Figure 5.7.

Interpretations

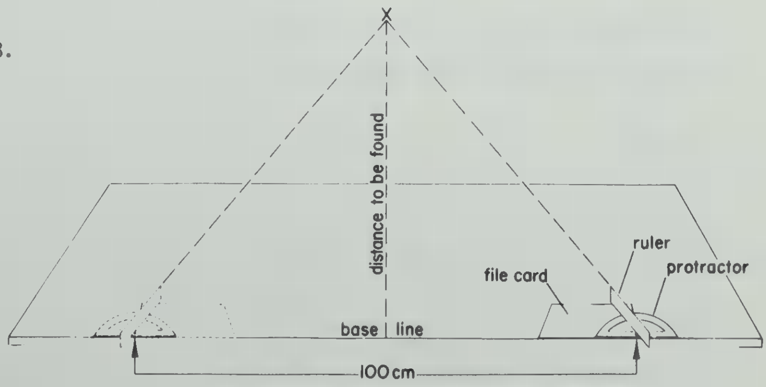
1. Did you notice any apparent change in the positions of the object and of the pencil? If so, describe the change.

Procedures (continued)

C. Place a table near a wall, with a long edge parallel to the wall. Tape two file cards along the other long edge of the table so their outside edges are 100cm apart (Figure 5.8).

D. Using a crayon or grease pencil, write a large X on an index card and tape the card to the wall at a height about level with the table top.

Figure 5.8.



E. Tape your protractor so that its central point for measuring angles is at the outside corner of one index card and its straight edge is along the base line, as shown in Figure 5.8. Hold a ruler so that its edge is directly above the center of the protractor, and sight the X along the ruler. Have a second member of your team read the number of degrees between the base line and the ruler. Record your results. (You may find it difficult to keep the edge of the ruler directly over the center of the protractor. If so, a pin can be placed upright over the center and the ruler held against it.)

F. Repeat Procedure E, using the outside corner of the other index card.

G. To calculate the distance between the mid-point of the base line and the X, make a scale drawing showing the measurements. Let a 10cm line on your paper represent the 100cm base line. Use your protractor to draw the same angles on the scale drawing that you measured on the table. Extend the two lines of sight on your scale drawing to form a triangle. The point where they meet represents the position of X. Record the distance between this point and the mid-point of the base line on your drawing. Use your scale drawing to calculate the distance from the base line to X. With a meter stick measure the distance between the base line and the X on the wall.

Interpretations

2. Is the calculated distance the same as the measured distance? If not, how would you account for any difference?

Procedures (continued)

H. Using similar procedures outdoors, determine the distance to an object that is much farther away.

Interpretations

3. In sighting the more distant object, were the angles formed by the ruler and base line larger or smaller than the angles measured in Procedures E and F?

4. Under what two conditions do you expect lines of sight from different locations toward the same object to be in nearly the same direction?

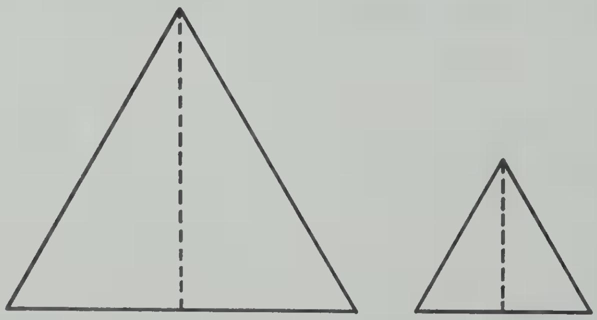
PROBLEMS

1. Figure 5.8 shows the distant object located directly between the two ends of the base line. Would the method for finding distance work if the object were off to one side?

INVESTIGATION 5.3: Measuring Distance Indirectly

The major purpose of this investigation is to have students use triangulation to measure distances. In Section Twelve, triangulation will be discussed as a way to measure the distances to stars relatively close to us. Most students should have little difficulty performing the investigation. If they have trouble with triangulation you might wish to briefly discuss what is meant by similar triangles. You could state that similar triangles are triangles whose angles are equal even though the triangles may not be the same size. A simple sketch such as Figure T-5.2, drawn on the chalkboard should make this point clear. Use of the term "triangulation" has been avoided in the student text, but you may wish to use it.

Figure T-5.2.



In Procedures A and B students will observe a principle of triangulation, that lines of sight toward the same object from different viewpoints lie in different directions. Do not spend much time on this part of the investigation. It is intended merely to arouse interest and serve as an introduction.

Procedures

A.-B. No comment.

Interpretations

1. Both the pencil and the object should appear to move. The pencil will appear to move through a greater distance because it is closer.

As an illustration of the fact that both eyes normally are used in estimating distances (binocular vision) you may wish to suggest the following: Two students stand facing each other at a distance of about a meter. One student holds a pencil horizontally in front of him. The second student covers one eye and attempts to touch the tip of that pencil with the tip of his own pencil. The process is repeated, but with both eyes open, and is found to be easier. (Note: If a student attempts this procedure while holding a pencil still with one hand and trying to touch it with a second pencil in the other hand, he may find it easy. This is because information about the location of the stationary "target" is being sent to his brain from the muscles of the arm holding the target. For this reason most people can touch fingertips with both eyes closed.)

Procedures (continued)

C. How your students set up the distance to be measured depends in large part on the physical arrangement of your room. Taping the card marked X to the back of a chair of appropriate height will work. Ideally the card should be placed about two or three meters from the base line.

Also, perhaps tables in the cafeteria can be used. This will enable all teams to work simultaneously. Cafeterias are usually large enough to ensure that teams will not be in each other's way. If the investigation is to be done with one table in the classroom, several teams can take turns and then compare their data.

D. No comment.

E. Precision in placing the protractor and reading the angles is important in obtaining agreement between the calculated distance and the actual distance.

F.-G. No comment.

Interpretations

2. The distance from the base line to the X on the wall ought to be ten times the distance measured in the drawing. Differences between the calculated and actual distances may be due to inaccurate readings or recordings, or inaccuracies in the construction of the scale drawing.

Procedures (continued)

H. For this outdoor activity, only one table is necessary. You might have teams take turns sighting a distant tree or flagpole.

Interpretations

3. Students should observe that the angle between the ruler and the base line increases when sighting a more distant object.

4. Lines of sight will be more nearly parallel if the distance to the object is very great or if the viewing points are close together compared with the distance to the object.

PROBLEMS

1. The problem can best be solved by actual investigation. Students will find that the triangle need not be isosceles.

OPTIONAL INVESTIGATION: Measuring Distance with the Astrolabe

This investigation is not included in the student text. It provides additional activities that may be performed with the astrolabe.

Materials (per team)

Astrolabe
Meter stick
Protractor
Chalk
Masking tape

Procedures

A. To students: Stand or sit with your head a measured two meters (2m) from a wall. Select two target points on the wall. One point should be directly above the other. Use the astrolabe to measure the vertical angle to each. With a meter stick, measure the distance between the two points.

(To the teacher: Before class, mark target points on the wall with chalk or masking tape.)

The distance of 2m is chosen because it will produce a sketch which, when drawn to a 1:10 scale, fits nicely on a standard sheet of notebook paper. The observer's head--not the instrument-- should be 2m from the wall.

Interpretations

Ask students the following three questions. Student responses will vary for each question.

1. What is the astrolabe reading for the lower point? Be sure to state whether you are sighting up or down to it.

2. What is the astrolabe reading for the higher point?

3. What is the distance in meters between the two points?

Procedures (continued)

B. To students: In your notebook make a sketch showing the results of Procedure A and Interpretations 1-3. The sketch should be to a scale of 1:10--that is, one tenth the size of the actual measurements. Represent the 2m from you to the wall by drawing a horizontal line 20cm long. At one end of the horizontal line place an X to represent your location. At the other end draw a vertical line to represent the wall. Use your protractor to lay out the angles recorded in Interpretations 1 and 2.

(To the teacher: See Figure T-5.3.)

To students: Measure the distance between points on your diagram.

Response: Though the distances are scaled down, the angles remain constant and the distances are 1/10 the actual distance.

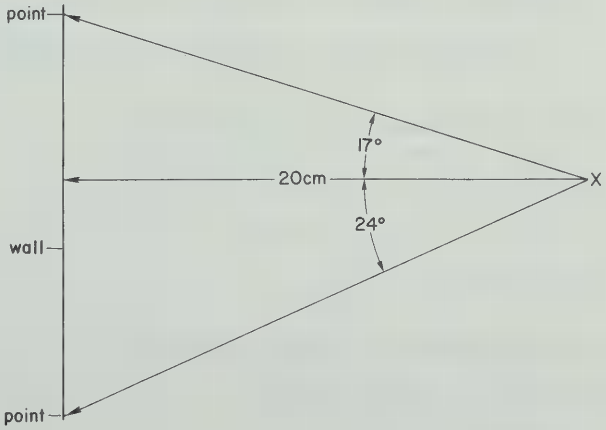


Figure T-5.3. Sample diagram for Procedure B.

Interpretations

4. Ask students: What is the distance in cm between the two points in the sketch?

Response: Answers will vary.

5. Ask students: How does this distance compare with the distance recorded in Interpretation 3?

Response: The distance, in cm, between the points on the diagram should be 1/10 of the distance between the actual points. Five percent error is quite acceptable. This means that if the distance between the actual points is 2.8 meters, the distance in the sketch should be about 28 centimeters. Answers between 26.5cm and 29.5cm are quite acceptable.

Procedures (continued)

C. To students: Again position yourself so that your head is 2m from the wall. Select another pair of points. Sight on the points, as in Procedure A, but do not measure the distance between them. Make a 1:10 scale drawing, as in Procedure B.

(To the teacher: The purpose here is to have students gain confidence in their ability to calculate the distance between points.)

Interpretations

6. Ask students: What is the distance in cm between the two points in your sketch?

Response: Answers will vary.

Procedures (continued)

D. To students: Now measure the distance between the two points on the wall.

Interpretations

7. Ask students: What is the actual distance in meters between the two points?

Response: Answers will vary. However, the actual distance should be about ten times the distance measured on the sketch.

PROBLEMS

Ask students: Use your astrolabe to measure angles to the top and bottom of a building, a tree, a flagpole, or other object. If the object is tall, you should stand more than 2m away from it. Then use a scale drawing to calculate the height of the object.

(Teacher: Students should not feel obligated to use a 1:10 scale factor; they should choose a scale that is convenient for the distances involved. Thus, if a building approximately 50m high is to be measured, the student should stand at least that far from it for good results. His sketch might be made to a scale of 1:100. This would produce a sketch of about .5m x .5m, which would fit on a large sheet of wrapping paper or on a chalkboard.

This would be an appropriate time for a "lab practical" type of test. One test item might call for the use of an astrolabe to measure a known (to the teacher) angle. If you do this be sure the head of every student is at the same height when sightings are taken. Otherwise discrepancies will be introduced. This problem may be avoided by having each student rest the astrolabe on the back of a particular chair. This would tend to keep head height and distance from the wall constant.

Or you might give out an entire problem to be solved either individually or by groups. Masking-tape targets arranged in pairs could be placed on the wall at a number of different stations. A point 2m from the wall could be marked on the floor with tape. This would speed things up and also remove the opportunity for students to measure the distance on the wall.)

INQUIRY DEMONSTRATION: Building a Water Thermometer

The purposes of the demonstration are to acquaint students with the principles of the thermometer, to allow them to relate these principles to design features of thermometers, to introduce the Celsius (metric) temperature scale, and to familiarize students with the thermometer, a device whose use will be required in later investigations.

Materials

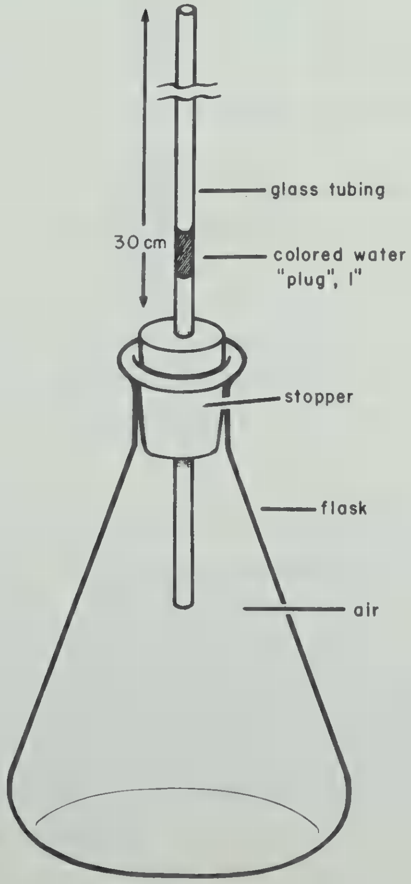
Food coloring (vegetable dye)
Erlenmeyer flask, 250ml
Erlenmeyer flask, 125ml
One-hole stopper, 2
Glass tubing, 6mm O.D.
Bunsen burner
Ring stand
Triangular file
Ring stand clamps, 2

Procedures

Set up the apparatus as shown in Figure T-5.4 before the beginning of class.

The "plug" of colored water should be about one inch in length and visible above the stopper with the apparatus "at rest" at room temperature. Invite the students to observe the apparatus. While calling attention to the water "plug," grasp the flask with both hands and squeeze with an apparently great effort. (Do not actually squeeze the flask with great force.) The plug will move up the tubing as your hands warm the air in the flask. Allow the plug to rise about six inches, then remove your hands.

Figure T-5.4.



Call for observations and possible reasons for the movement of the plug. Students are likely to say that: (1) Pressure on the walls of the flask caused the change; and/or (2) Heat from your hand was responsible. Try to draw both responses from the class.

Ask the class to describe an experiment that would show if pressure alone would cause the change. (Repeating the demonstration with an insulating material such as folded newspaper between the hands and the flask.)

Ask the class to describe an experiment that would show if heat alone could cause the change. (Heating the container with a flame will cause the plug to run out over the top of the tubing. Cooling will force the plug down into the flask.)

Ask the class what the apparatus might be used for. (Someone should suggest that it might be used as a thermometer.)

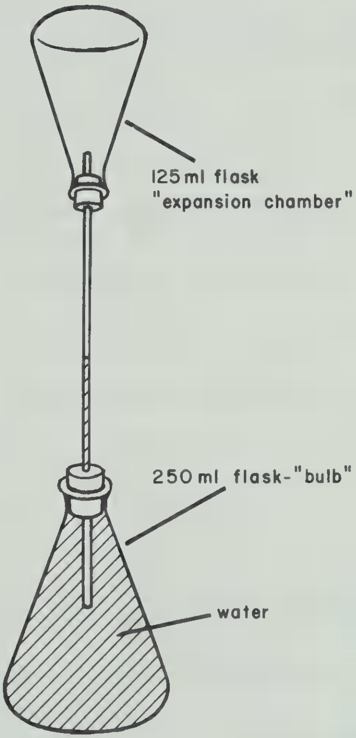
What drawbacks does such a thermometer have? (Two obvious shortcomings are: (1) A rather long piece of tubing must be used to measure large temperature changes, and (2) The accuracy is questionable since the water plug might run out the open end or evaporate.)

Ask the class how these same materials could be used to make a better thermometer of reasonable size. (One alteration would be to fill the flask with water so that a solid column of water extends into the tubing. This thermometer would indicate temperature change with much smaller increments in height than the air thermometer. You may want to demonstrate this to students.)

It may be suggested that the problem of evaporation could be solved by sealing the open (outside) end of the tubing. This can be done by melting the end of the tubing in a flame. Then drive out some of the air in the tubing by warming the portion above the stopper in the flame. Insert the tubing (and stopper) into the flask. As the air in the tubing cools, water will enter the tubing. Note: Cold water

will shatter hot tubing. CAUTION: Such an apparatus may explode if too much heat is applied. This defect can be demonstrated safely if you insert the stopper loosely and then gently heat the flask. If done carefully, the stopper will pop out and the tubing will tilt to one side. Be careful that this does not overturn the flask.

Figure T-5.5.



Ask the class to suggest a modification of the apparatus which would overcome the disadvantages of both open and closed tubes. (The addition of an expansion chamber, Figure T-5.5, would solve both types of problems.)

Two functions are served by the expansion chamber: (1) Once the air in the top flask becomes saturated, error, due to evaporation from the water column, is reduced, and (2) The water column can move a larger distance before critical pressures are produced.

When you demonstrate such a thermometer, make sure that the stopper in the bottom flask is loosely fitted and that adequate support is provided for the apparatus. DO NOT HEAT THE "BULB" SO MUCH THAT WATER IS DRIVEN INTO THE EXPANSION CHAMBER.

FOR FURTHER ACTIVITY

After the demonstration you may want to hand out thermometers of the type students will use in later investigations and assign the following task. Ask students to do the following:

1. Examine the thermometer. In your notebook prepare a sketch of the thermometer with labels which describe the purpose of each part of it. Note whether the thermometer is marked in Celsius (C) or Fahrenheit (F) degrees. (See Figure T-5.6 for a sample response. Responses will depend upon the type of thermometer available. The Celsius scale was formerly known as the Centigrade scale. On it, the temperature of melting ice is $0^{\circ}C$ and the temperature of boiling water is $100^{\circ}C$. On the Fahrenheit scale ice melts at $32^{\circ}F$ and water boils at $212^{\circ}F$. A conversion chart is supplied at the back of the book for use by students.)

2. Read the thermometer and record the air temperature of your classroom. Determine the temperature of tap water and your body temperature. Approximate body temperature may be obtained at the crook of the elbow by folding the forearm over the bulb.

(An average air temperature for the room can be found. This would be a good opportunity to point out the fact that there may be variations in thermometers which lead to differences in readings.)

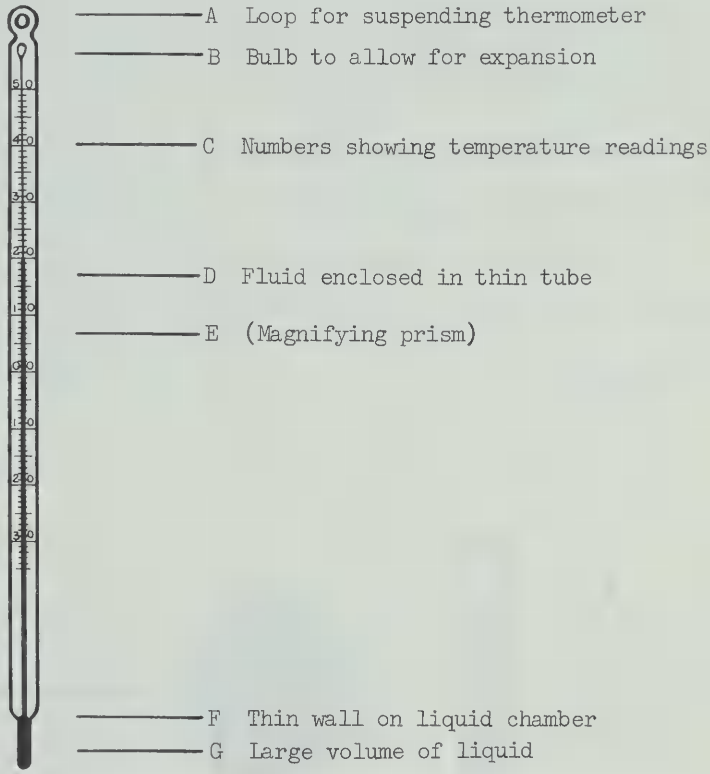

A Loop for suspending thermometer
B Bulb to allow for expansion
C Numbers showing temperature readings
D Fluid enclosed in thin tube
E (Magnifying prism)
F Thin wall on liquid chamber
G Large volume of liquid

Figure T-5.6.

INVESTIGATION 5.4: Volume

A method of measuring volume will be examined in this investigation. The volume of an object is the amount of space it occupies. You may be used to expressing volume in pints, quarts and gallons. In the metric system volume is expressed in liters and milliliters. A liter is a little larger than a quart. The volumes of samples smaller than a liter are expressed in milliliters (abbreviated ml). There are one thousand (1000) ml in a liter.

The volume of a liquid can be measured in an instrument called a graduated cylinder. It is simply a flat bottomed, straight-sided tube with marks and numbers to indicate volume. See Figure 5.9.

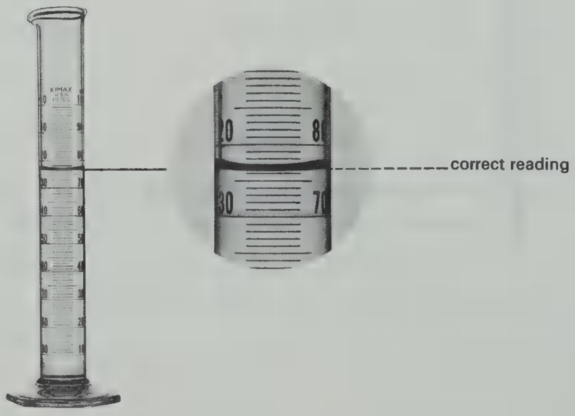


Figure 5.9.
The correct reading of a graduated cylinder is taken from the lowest point of the curve formed by the liquid.

The volume of any liquid can be found simply by pouring it into a graduated cylinder. The volume of a solid object can also be determined with a graduated cylinder. Since very few solids fit snugly into a graduated cylinder, it is necessary to partly fill the cylinder with a liquid such as water. When a solid object is placed in the container, the liquid level will rise. The change in the volume readings is equal to the volume of the solid object.

Materials (per team)

100 ml graduated cylinder

Solid objects, 3

Masking tape

Procedures

A. Copy Figure 5.10 into your notebook.

	Object #1	Object #2	Object #3
Description of object			
Volume with object			
Volume without object			
Change in volume			

Figure 5.10. Volumes

B. Pour between 35ml and 50ml of water into the 100ml graduated cylinder. Read the volume as accurately as you can (see Figure 5.9). Record the volume on your copy of Figure 5.10 in the third space under Object #1.

C. Select one of the objects and briefly describe it in the first space under Object #1. Place the object in the graduated cylinder so that it is completely underwater. Record the new (total) volume in space two under Object #1. Remove the object from the graduated cylinder. Subtract the volume without the object from the volume with the object and record the answer in the last space under Object #1. The volume you have calculated is the volume of Object #1.

D. In a manner similar to Procedures B and C, complete the table for the other two objects.

Interpretations

1. What are some of the limitations on this method of finding the volume of an object?

TEACHER MATERIAL

INVESTIGATION 5.4: Volume

The purpose of this investigation is twofold. It should develop laboratory techniques, particularly measurement of volume. It should provide data which will be needed in the next investigation, Density.

Materials

The graduated cylinder need not be 100ml, as long as it will accommodate the objects to be immersed in water.

The three solid objects should be different kinds of material. One of the three should float. While different teams may have identical sets of objects, it would also be possible to have different materials for each team. The objects should not be porous (like a sponge) and must fit inside the graduated cylinders. The objects for which sample data is given are: a two-ounce lead fishing weight, a 1/4" x 5" piece of hardwood dowel, and a small piece of rock (basalt).

Since the next investigation is a continuation of this one, each team should identify its specimens for use during the next laboratory session.

<u>Procedures</u>

A. No comment.

B. The amount of water needed depends on the objects. It is advisable to test the objects before class to be sure the amount of water specified will cover the objects and still give a reading with the object submerged.

C.-D. See Figure T-5.7 for sample data. Advise students to use a straightened paper clip or pencil tip to force the floating object underwater.

	Object #1	Object #2	Object #3
Description of object	fishing weight	wooden dowel	rock
Volume with object	40.0ml	45.5ml	50.0ml
Volume without object	34.5ml	39.5ml	40.0ml
Change in volume	5.5ml	6.0ml	10.0ml

Figure T-5.7. Sample data for Procedures C and D.

Interpretations

1. Some limitations on this method are that the object must fit inside a graduated cylinder and it must not dissolve in or react with the liquid that is used.

VOLUME AND DENSITY

The volume of a sample of material will not serve to identify what it is made of. It is possible to have a large piece of material and a smaller piece of the same kind of material. The larger piece will naturally have the larger volume. It is possible however to measure something that is characteristic of a pure substance, and will be helpful in identifying the material. If you know both the weight and the volume of a sample, you can calculate its density. Density is found by dividing the weight of any object by its volume. The density of a large block of ice is the same as the density of a small ice cube. The weight of a large block of ice is greater than the weight of an ice cube, but the volume of the block is proportionally bigger. When the weight of any sample of ice is divided by the volume of that sample, the answer is always the same. The density of every piece of pure ice is the same. A block of gold weighs more than a piece of ice the same size. The density of gold is, therefore, greater than the density of ice.

You have already measured the volumes of several objects. To find each density, you must find out how heavy each object is. When metric system equipment is used to measure weight, the answer is often expressed in grams. At the time the metric system was developed, the size of a gram was chosen so that one ml of water weighs one gram. Therefore in the metric system, the density of water is one gram/ml. Because of this fact, it is relatively easy to find densities of other substances.

<u>When the weight of an object is divided by the weight of an equal volume of water, the result is the density of the object in grams per ml</u>. It may be surprising that the <u>system</u> for measuring weight is not important. As long as the weight of the object <u>and</u> the weight of an equal volume of water are measured in the <u>same</u> system, the density will be in grams per ml.

INVESTIGATION 5.5: Density

In this investigation a weight gauge is used to obtain data about weight. The values will be the number of "weight units" rather than the ounces or pounds you are familiar with. One reason for doing this is to show how easily densities can be found. You don't need elaborate equipment.

Materials

Three solid objects used in Investigation 5.4
Weight gauge
Data from Investigation 5.4
Graduated cylinder

Procedures

A. Copy Figure 5.11 into your notebook.

	Object #1	Object #2	Object #3
Reading with the object			
Reading empty			
Units of weight for the object			

Figure 5.11. Weight gauge readings for objects.

B. Tape the weight gauge to the edge of a table or desk so that the rubber band, paper clips and cup hang down along the scale on the card (see Figure 5.12).

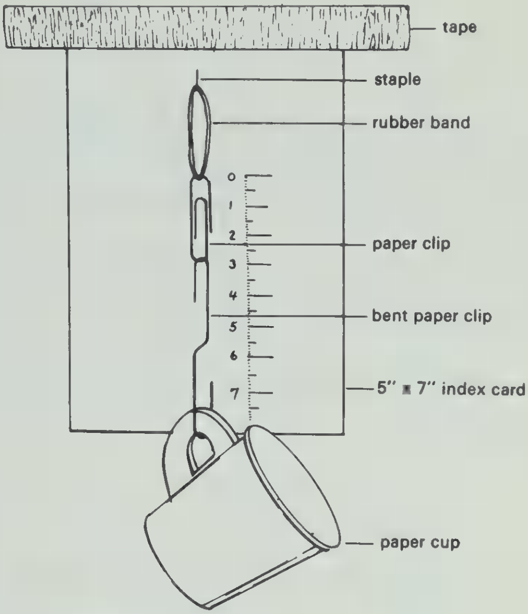


Figure 5.12. Weight gauge.

C. Read the position of the lower end of the rubber band on the scale. Be sure your eye is level with the end of the rubber band when you take the reading. Record the reading on your copy of Figure 5.11 in the second space below Object #1. Place Object #1 in the cup and again read the position of the lower end of the rubber band. Record the reading in the first space below Object #1 on your copy of Figure 5.11. Remove the object from the cup. Subtract the reading empty from the reading with the object and record the answer in the third space below Object #1.

D. In a manner similar to Procedure C, complete the table for the other two objects.

E. Copy Figure 5.13 into your notebook.

	Object #1	Object #2	Object #3
Reading for volume of water equal to volume of object			
Reading empty			
Units of weight for water equal to volume of object			

Figure 5.13. Weight gauge readings for water.

F. Read the position of the lower end of the rubber band on the scale. Record the reading on your copy of Figure 5.13 in the second space below Object #1. Refer to Figure 5.10 to find the volume of Object #1. Into a graduated cylinder, measure a volume of water equal to the volume of Object #1. Pour the water into the cup on the weight gauge and read the position of the lower end of the rubber band on the scale. Record the reading in the first space under Object #1. Empty the water from the cup.

Subtract the reading empty from the reading for the volume of water equal to the volume of Object #1, and record the answer in the last space under Object #1.

G. In a manner similar to Procedure F, complete the table for the other two objects.

Interpretations

1. Calculate the density of each object. (Recall that when the weight of an object is divided by the weight of an equal volume of water, the result is the density of the object in grams per ml.) In answering this interpretation, show your calculations as well as the values you get for the densities.

2. If the density of an object is less than the density of water, what does the object do when it is placed in water?

PROBLEM

A metal rod has a density of six grams per ml. If it is cut in half will each piece have a density of three grams per ml? Give reasons to support your answer.

INVESTIGATION 5.5: Density

The purpose of this investigation is to show how the density of objects may be determined. The concept of density will be used in the next section to investigate the effects of salinity and temperature on water.

Materials

The small graduated cylinder should be large enough to accommodate a volume of water equal to the volume of the largest object.

You may want students to prepare their own weight gauges at home, but you will probably get more uniformity by having a few students prepare enough for the entire class. The card should be stiff enough to permit reliable readings. It can be an index card, cardboard or plywood. The scale can be marked directly on the card or a ruler may be taped to the card.

The rubber bands must be selected with care. Be sure they are not too stiff, and that the change in length increases in proportion to the load on them.

The cup can be plastic or paper, or a small tin can. If you have balances or commercially produced spring scales and want to use them, they will probably give more accurate data than the homemade weight gauge. If you do not have balances on hand, it is not recommended that you buy them for this course.

Procedures

A. No comment.

B. Have the students check to be sure the rubber band, paper clips and cup move smoothly along the card or scale.

C.-D. See Figure T-5.8 for sample data.

	Object #1	Object #2	Object #3
Reading with object	133	102	114
Reading empty	100	100	100
Units of weight for object	33	2	14

Figure T-5.8. Sample data for'Procedures C and D.

E. No comment.

F.-G. See Figure T-5.9 for sample data. You may find it advisable to provide eye droppers for students to adjust the volume in the graduated cylinder.

	Object #1	Object #2	Object #3
Reading for volume of water equal to volume of object	102.5	102.5	104.5
Reading empty	100.0	100.0	100.0
Units of weight for water equal to volume of object	2.5	2.5	4.5

Figure T-5.9. Sample data for Procedures F and G.

Interpretations

1. Calculations based on sample data:

Object	#1	#2	#3
Calculation	$33 \div 2.5 = 13$	$2.0 \div 2.5 = 0.8$	$14.0 \div 4.5 = 3$
The density is about	13g/ml	0.8g/ml	3g/ml

It should be noted that these values are only approximate, due to lack of precision in weighing. For example, the accepted value for the density of lead is 11.35g/ml and not 13g/ml. The densities are of the right order of magnitude and the percentage error is reasonable.

Different teams cannot be expected to get exactly the same answers for a substance, and they should understand that such variation is more likely due to experimental error than to variations in density.

2. If the density of an object is less than the density of water, the object will float in water.

PROBLEM

The density of each piece will still be 6g/ml. One basic idea of this investigation is that density is an identifying characteristic of a substance. If the rod is cut in two, each piece will be half as heavy and half the volume of the original rod. The smaller weight divided by a smaller volume will give the same answer as a larger weight divided by a larger volume for the same substance.

Section Six:

Some Properties of Water

PREVIEW

Since more than three-fourths of the earth's surface is covered by water it is appropriate that an earth science course should deal with the subject of oceanography. Most aspects of oceanography, however, are marine applications of other sciences: geology, meteorology, biology, etc. For this reason, Section Six deals with only a few of the topics which might normally be considered under the heading of "oceanography."

Investigation 6.1 provides instructions for constructing a simple but sensitive hydrometer. With it students measure the densities of three salt solutions. It is seen that the density of sea water is about 1.025 grams/ml and that the addition of more salt to a solution increases its density (Investigation 6.2).

In Investigation 6.3 density of water is also seen to be a function of temperature, with higher water densities corresponding to lower temperatures.

The effect of evaporation on salinity, and hence density, is investigated by students in Investigation 6.4.

A reading selection and an associated set of problems introduce students to some of the complexities of horizontal and vertical motions of water in the oceans. Upwelling and its implications for marine life are discussed.

Dependence of marine life on materials provided from the surface, (as well as those brought up from the depths) is considered in Investigation 6.5, in which the presence of dissolved carbon dioxide is marked through use of an indicator, and gas exchange between various solutions and the atmosphere is studied.

The dependence of marine life upon depth has thus been established. An investigation on depth-sounding by means of a lead-line follows. Students deduce bottom profiles as a result of limited and then more extensive observations.

Following an Inquiry Demonstration and reading selection on sonar, a more sophisticated method for depth ranging, the section closes with a series of ocean-related questions to the student which will be pursued in later sections of the text.

Section Six:

Some Properties of Water

Some sciences are concerned with one particular type of thing or with one set of processes. Botany, for example, deals with plants regardless of where they may be found . . . on the surface of the earth, in lakes, or even on other planets.

Other sciences are concerned with a particular location. They include all things and processes found in that one place. Oceanography is such a science. It deals with just about every imaginable aspect of the oceans: their tides, their weather, the living things in them, the geology of the sea floors, and so forth.

In Section Six you will consider certain properties of water itself. This section may thus be thought of as an introduction to the subject of oceanography. In later sections there will be further references to oceans, their effect on climate, life forms which have lived there, etc. You may find it interesting to watch for material which might be thought of as either oceanography or some other subject.

Limnology, the science of fresh-water ponds, lakes, and streams is also introduced through a study of water. If you live near an ocean or lake you may wish to start thinking of observations and investigations you could conduct along the shoreline or from a pier or bridge.

People gain information about the world from their five senses--sight, smell, hearing, touch and taste. But the senses can be deceived. You may have discovered this in the last section when you measured distances. Observations can be made more accurate if scientific instruments are used. The techniques of measurement are well worth learning. They can be used to look for patterns and help solve problems.

In this section instruments will be used to study the behavior of water. Properties discovered for small samples of water may be helpful in developing models for the behavior of water in lakes and oceans.

Figure 6.1. The edge of the sea. Cape Cod, Massachusetts.

INVESTIGATION 6.1: The Hydrometer

A hydrometer consists of a weighted bulb and a sealed cylinder. When placed in a liquid, it floats; part of the cylinder remains out of the liquid. The density of a liquid is found by comparing the liquid level with a scale sealed inside the hydrometer. In this investigation you will build a hydrometer. It can be used to study some of the factors affecting the densities of liquids.

Materials (per team)

- Test tube, 18 x 150mm
- One-hole stopper size #1
- Glass tubing, 6mm O.D. (11cm long)
- Index card
- Scissors
- Candle
- Matches
- Ruler, metric-English
- Lead shot (#4)
- Graduated cylinder, 100ml
- Solutions A, B and C

Procedures

A. Use a sharp pencil to mark the long edge of an index card. (Figure 6.2) Place a light mark every 1/16 inch. Every fifth (5th) mark should be darkened so the scale will be easier to read. Cut the marked edge to form a narrow strip that will fit inside the glass tubing.

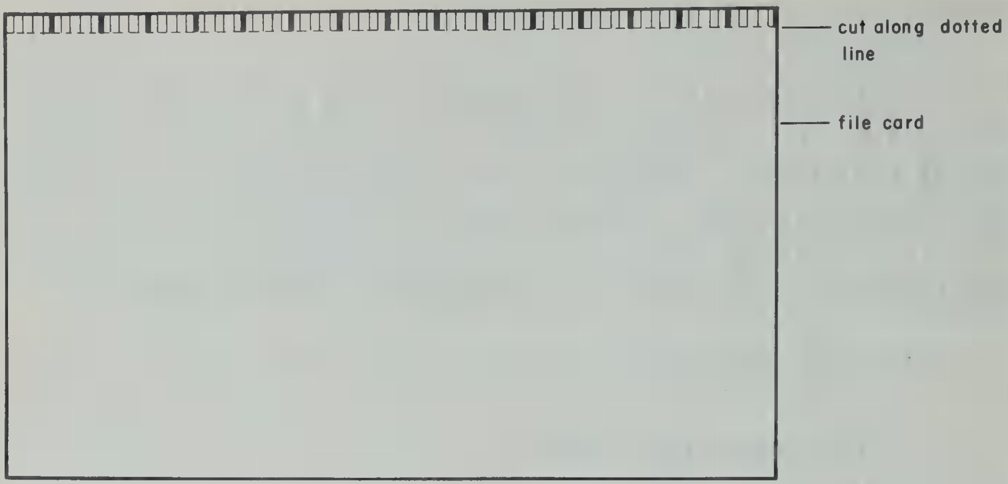


Figure 6.2. Scale strip should be just wide enough to fit inside glass tubing.

B. Light the candle. Place the marked strip inside the tubing. Hold the tubing horizontal and seal one end with a small amount of wax dripped from the candle. The wax should form an airtight seal and also hold the scale strip in place. Trim off any paper outside the wax seal.

C. Use water to moisten the outside of the unsealed end of the tubing. Carefully insert the moistened end into the stopper.

D. Place about 50 lead shot in the test tube and fit the stopper in place with the scale extending above the test tube. Your hydrometer should look like the one shown in Figure 6.3.

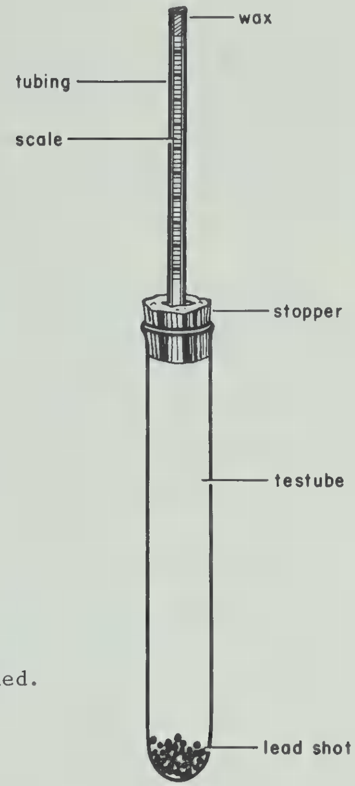


Figure 6.3. The hydrometer assembled.

E. Obtain about 85ml of "standard" water in a graduated cylinder. This water must be specially prepared so that its density is 1.000 gram per ml.

F. Lower the hydrometer into the graduated cylinder. If the hydrometer sinks to the bottom, remove it and take out four or five lead shot. If the hydrometer floats so that most of the scale is out of the water, add one or two lead shot to the test tube. Add or remove lead shot until the hydrometer floats with the <u>second</u> darkened line from the top of the scale slightly above the water.

G. Adjust the level at which the hydrometer floats by tightening the stopper slightly so the second darkened mark is at the water surface. Once the level has been set, do not remove or jar the stopper. This would make the instrument inaccurate until readjusted in "standard" water.

H. Since the "standard" water has a density of 1.000g/ml, the second darkened line represents a scale value of 1.000g/ml. Other density values in grams per ml are shown in Figure 6.4. Return the standard water to the proper container. Use your hydrometer and graduated cylinder to determine the density of tap water.

I. Determine the densities of salt solutions A, B, and C. Be sure to follow instructions regarding disposal of the solutions. Record the density of each solution in your notebook.

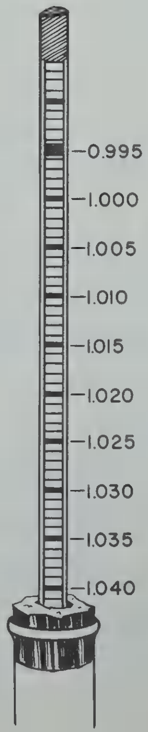


Figure 6.4. Enlargement of scale in tube.

Interpretations

1. Sea water has a density of 1.025 grams per ml. Which solution has a density nearest that of sea water?

2. Which solution do you think contains the most salt? Why?

TEACHER MATERIAL

INVESTIGATION 6.1: The Hydrometer

In this investigation students will construct and calibrate hydrometers for use later in the section.

Materials

Glass tubing of 6mm outside diameter should be cut in lengths of 11cm and fire polished on both ends. If burners and files are available, students could prepare their own tubing after suitable instruction. They should be cautioned about sharp edges on new ends and the danger of burns from hot tubing.

The one-hole stoppers, size #1, must be cut in half and the upper (larger diameter) portion discarded. A full size stopper makes the hydrometer top heavy. The stopper can be cut using sharp tin snips or heavy duty shears.

Number four lead shot may be purchased locally at sporting goods stores that carry reloading equipment.

The "standard" water used to calibrate the hydrometers can be made by adding ditto fluid (methyl alcohol) to tap water until a density of 1.000 gram per ml is obtained. The water-alcohol mixture should be at room temperature. (A commercial hydrometer used for urine analysis provides the accuracy and range needed for solutions used in this section.) The solution should be stored in a closed container to prevent a change in density by evaporation. Although pure water at 4°C has a density of 1.000g/ml, its use as a standard is not recommended. Maintaining the temperature within tolerance is an unnecessary complication.

The three salt solutions may be made as follows:

Solution A: Add 35 grams of sodium chloride (table salt) to 965ml of distilled water. The salinity of this solution is approximately the same as that of sea water. At room temperature (20°C) the density will be a little less than 1.025g/ml. Although the salinity of Solution A is the same as that of sea water, its density is less because of the effect of temperature. This effect will be studied in the next investigation.

Solution B: Add 300ml of distilled water to 300ml of Solution A.

Solution C: Add 500ml of distilled water to 100ml of Solution A.

Procedures

A. With the equipment specified for the student hydrometer, marks 1/16 inch apart correspond to density differences of 0.001g/ml.

B. No comment.

C. Caution students not to force the glass into the stopper because it might break and cut them. Using water as a lubricant and a twisting motion while inserting the tubing will generally prevent breaking.

D. No comment.

E. The standard should be stoppered until students are ready to use it.

F. No comment.

G. Caution students not to handle hydrometers roughly after they have calibrated them.

H. If you want to save the standard, a labeled container should be provided.

I. Accuracy within 0.005g/ml is good. Student hydrometers will probably not be as accurate as commercial models.

If you want to save the solutions, labeled containers should be provided.

Interpretations

1. Solution A has a density nearest that of sea water.

2. Solution A is known to contain the most salt because its density is greatest and most different from the density of tap water.

Students may have difficulty in justifying their answers. Accept all suggestions.

INVESTIGATION 6.2: Density and Salinity

In this investigation you will look for a relationship between salinity (percent of dissolved salts present) and the density of water.

Materials (per team)

Hydrometer
Graduated cylinder, 100ml
Beakers, 600ml
4% salt solution
Stirring rod

Procedures

A. Determine the density of a 4% salt solution. Record your results in your notebook.

B. Pour 50ml of the 4% solution into a clean, dry beaker, and discard the remainder. Add 50ml of water to the beaker to make a 2% salt solution. Mix it thoroughly.

C. Measure and record the density of the 2% salt solution.

D. Pour 50ml of the 2% salt solution into a clean, dry beaker. Add 50ml of water and mix it thoroughly.

E. Measure and record the density of this solution.

Interpretations

1. What percent was the salt solution prepared in Procedure D?

2. Plot your data on a graph like the one shown in Figure 6.5.

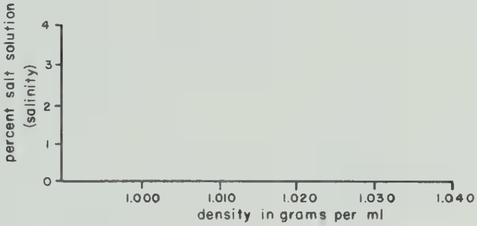


Figure 6.5. Graph of Density and % Salinity.

3. Use a graph to predict the salinity (percent salt) of sea water. The density of sea water is 1.025 grams per ml.

INVESTIGATION 6.2: Density and Salinity

In this investigation students see that the density of a solution is directly proportional to its salt content. They also note that sea water has a density of 1.025 grams per ml, corresponding to a salinity of 3.5%.

Materials

The four percent salt solution can be prepared by dissolving 25 grams of sodium chloride (table salt) in 600ml of water.

Baby food jars or plastic cups could be substituted for the beakers.

You might want to have one container of "standard" (1.000g/ml) water available in case students need to check or adjust their hydrometers.

Procedures

A.-E. No comment.

Interpretations

1. The salinity of the solution prepared in Procedure D is 1%.

2. Sample data are shown in Figure T-6.1.

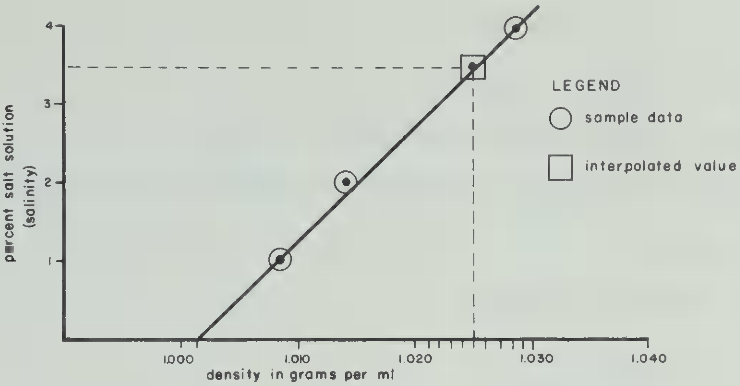


Figure T-6.1. Sample data for Interpretations 2 and 3.

3. See Figure T-6.1. The salinity is about 3.5%. You may find this a good opportunity to discuss graphing and interpolation of values not obtained directly.

INVESTIGATION 6.3: Density and Temperature

When salt is added to water the density of the liquid is changed. Adding heat to water may also change its density. Try to predict whether adding heat will increase or decrease the density of salt water.

Materials (per team)

Hydrometer
Graduated cylinder, 100ml
"Sea" water
Thermometer
Ice
Heat source
Matches
Ringstand and ring
Wire gauze
Large beaker

Procedures

A. Record your prediction of the effect of heat on the density of a solution.

B. Obtain 85ml of "sea" water in a graduated cylinder. Place the graduated cylinder in the beaker water bath and fill the beaker almost to the top with tap water.

C. Measure the temperature of salt water. If it is above 20°C add small amounts of ice to the water bath.

Stir the bath and the salt solution until the solution is 20°C, then remove the ice from the water bath. If the salt solution is below 20°C, warm the water bath until the temperature of the solution is 20°C. (Figure 6.6) When warming (or cooling) the salt solution you should carefully remove the graduated cylinder every so often, cover the open end with your hand, and turn it back and forth to mix the "sea" water. This will ensure even heating of the salt solution.

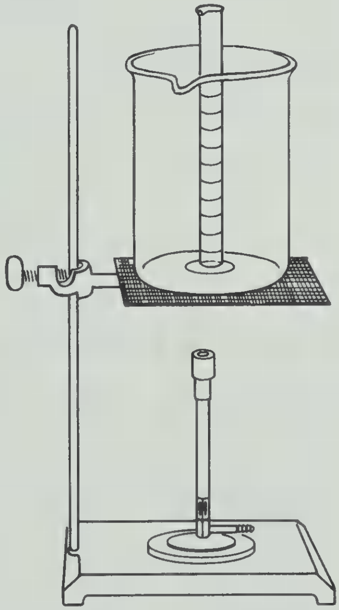


Figure 6.6. Water bath set up to warm salt water in graduated cylinder.

D. Measure and record the density of the salt solution at 20°C.

E. Continue heating (and mixing) the salt solution. Measure and record the density of the salt solution at 30°C, 40°C and 50°C.

Interpretations

1. Describe the effect of heat on the density of the solution.

2. What do you think would happen to the surface water in a warm lake as it cools off in the fall?

TEACHER MATERIAL

INVESTIGATION 6.3: Density and Temperature

The purpose of this investigation is show students that the density of a solution decreases as its temperature increases.

Materials

Tin cans seven inches high often may be obtained from the school cafeteria, local restaurants or bakeries. These may be used in lieu of beakers.

A "sea" water solution (3.5% NaCl) can be prepared by adding 35 grams of table salt to 965ml of distilled water.

If the temperature of tap water is above 20°C you will need ice.

Procedures

A. It does not matter whether or not students predict the effect correctly. The purpose of making a prediction is to involve the student, and perhaps make him more critical in his observations. He should not be disappointed if his prediction is not correct.

B. No comment.

C. Caution students not to change the salinity of the salt water by adding tap water or ice to the graduated cylinder.

D.-E. Each 10°C change should produce a change of about .003 grams per ml in density.

Sample data: 20°C, 1.027g/ml; 30°C, 1.024g/ml; 40°C, 1.021g/ml; 50°C, 1.018g/ml. (Results obtained from "sea" water prepared using tap water in place of distilled.)

Interpretations

1. Students should find that adding heat decreases the density.

2. The surface water sinks when cooled and is replaced by warmer, less dense water from below resulting in the fall "overturn" in the lake.

INVESTIGATION 6.4: An Effect of Boiling

You have seen that warming a solution can change its density. What do you think boiling would do to the density of a solution? Although previous investigations may have provided you with enough information to make a prediction, it would be wise to test the prediction experimentally.

Materials

- Hydrometer
- Graduated cylinder, 100ml
- Large tin cans, 2
- Thermometer
- "Sea" water
- Heat source
- Ringstand and ring
- Wire gauze

Procedures

A. Copy Figure 6.7 in your notebook.

Sample	Temperature in $^{\circ}C$	Density in grams per ml
Original Sample		
Boiled Sample		
Overnight Sample		

Figure 6.7. Data record for Procedures B, E and F.

B. Obtain about 400ml of "sea" water in a can. Measure the temperature of the sample and record the value in the chart. Then measure and record the density of the sample.

C. Pour about 200ml of the sample into one can and label it "overnight." Set this sample aside in a warm part of the room.

D. Heat the remaining salt water in a can until it begins to boil. Allow it to boil for six or seven minutes. Then remove the heat and allow the water to cool to a temperature of about 40°C.

Interpretations

1. Do you think the density of the salt water at 40°C will be greater than, less than, or the same as the density of the original sample? Record your answer in your notebook.

Procedures (continued)

E. Test your prediction by measuring the density of the sample. Then take the temperature of the sample and record the measurements in the second row of the chart.

Interpretations

2. What effect does boiling have on the density of the salt water?

3. Explain how boiling could cause the observed change.

4. What observations have you made that would support your answer to Interpretation 3?

Procedures (continued)

F. After the "overnight" sample prepared in Procedure C has been left out in the room for at least one day, measure and record its temperature and density.

Interpretations

5. Explain any changes in the density of the sample prepared in Procedure C.

PROBLEMS

1. At what latitudes would you expect the oceans to have the greatest salinity? Why?

2. River water that flows into the oceans is usually very low in salinity. How do you think the oceans became as salty as they are?

FOR FURTHER ACTIVITY

Design and carry out an experiment to test your answer to Interpretation 3. Write out your plan on paper and discuss it with your teacher before actually conducting the experiment.

INVESTIGATION 6.4: An Effect of Boiling

In this investigation students should find that when water evaporates from a sample of "sea" water the salinity of the remaining solution increases.

Materials

For five teams, prepare the salt solution by adding 70 grams of table salt (NaCl) to 2000ml of water.

The tin cans should hold at least 1000ml. Use of a smaller container may reveal water loss when the sample is boiled. Also, a large surface area increases evaporation from the sample left overnight.

If the relative humidity is high in your location, it may be advisable to place two or three 150-watt light globes over the cans to increase the evaporation rate.

Procedures

A.-B. No comment.

C. Direct students to place containers in an open warm area of the room. Do not leave them in a closed cupboard. In regions of high humidity, light bulbs should be used.

D. The suggested temperature of 40°C is not critical. Any temperature between 30°C and 50°C will do.

Interpretations

1. Students who base their prediction on the results of Investigations 6.2 and 6.3 may predict a density <u>less</u> than that of the original sample. Those who correctly predict an increase in density may already know the effect of evaporation on salinity and should be directed to verify the basis for the prediction by completing "For Further Activity."

<u>Procedures</u> (continued)

E. The density should be greater for the boiled sample.

Interpretations

2. Boiling increases the salinity and therefore the density of a salt solution.

3. When a salt solution boils, water molecules escape, reducing the liquid volume. Salt remains in the solution and, as a result, the same amount of salt is in a smaller volume of solution. Thus the density is increased. In this case, the <u>decrease</u> in density caused by raising the temperature is overshadowed by the <u>increase</u> in density due to increased salinity.

4. Any reasonable observation should be honored. The appearance of "steam" over the boiling solution and the reduction in volume of the boiled sample both indicate water loss.

<u>Procedures</u> (continued)

F. If lamps are used, samples should be allowed to cool to the temperature of the original sample before measuring density. Evaporation should cause an increase in density.

Interpretations

5. The explanation is similar to that in Interpretation 3. In this case, water loss is not as great and the effect is smaller.

PROBLEMS

1. Students may suggest that evaporation and the resultant increase in salinity should be greatest near the equator since temperatures average highest in the tropic region. Actually, salinity is greatest between 20° and 30° latitudes in both hemispheres. Large precipitation amounts and high humidity reduce the net water loss nearer the equator. The next reading section should help students to understand this.

2. Rain water dissolves salts from the soil and carries them eventually to the ocean. Water evaporates from the ocean and leaves the salt behind. Over billions of years this process has made the oceans increasingly salty.

FOR FURTHER ACTIVITY

Students could measure water loss by measuring volumes before and after boiling.

Evaporated water may be collected by folding a large square of heavy aluminum foil to form a pointed cup in the same way a filter paper is folded to fit a funnel. Put about 20ml of cold tap water in the aluminum cup and fold the edges over the container to support it above the boiling water. For a minute or so, water vapor can be seen to condense on the cool aluminum and drip back into the boiling sample.

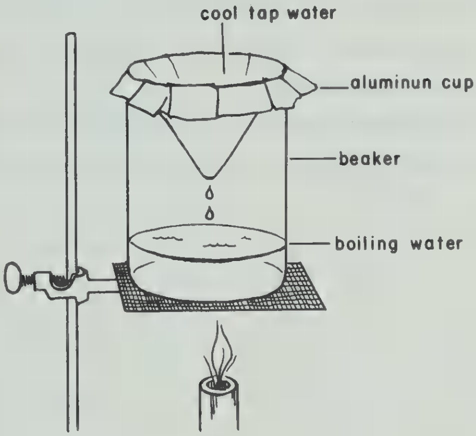


Figure T-6.2.

THE SALT SEA

Many different kinds of salts are dissolved in the ocean. All of them contribute to its salinity or saltiness. Sodium and chlorine make up 85% of the salt. These are the same ingredients found in ordinary table salt. The inclusion of four more substances (magnesium, calcium, potassium and sulfate) brings the total up to 99% of the salts in the ocean.

A large number of samples from different locations has been studied. Although the amount of dissolved material per ml may vary from one sample to another, the proportions of the different substances stay the same. It thus seems that water may be added to or taken away from the oceans, but the salt always remains in the sea. Near the mouth of a river or in places where it is raining the salinity may be lower than average. Where water is being removed by evaporation or by freezing, the salinity may be higher than average. What effects could these changes have on sea water, and on the oceans?

CIRCULATION IN THE OCEANS

Careful study of surface currents in the Atlantic Ocean shows that more water flows north across the equator than flows south!

What happens to the extra water? Is there actually a yearly increase in the amount of water in the North Atlantic? Observation shows that this is not the answer. Could the surplus water be evaporating, thus keeping sea level constant? The rate of evaporation at the latitude of the North Atlantic is not high enough. No large-scale movement of moisture laden air from north to south has been detected.

The best model appears to lie in thinking of currents deep beneath the surface which return as much water to the South Atlantic as leaves it along the surface. There must, then, be different factors controlling water movement (currents) at the surface and at depth. What are these factors? And what might cause surface water to sink or water from great depths to rise?

Surface currents seem to result primarily from the pattern of prevailing winds. Other things, such as rotation of the earth and the presence of continents give the circulation a complex pattern. There is little doubt that these currents play an important part in transporting heat from the tropics to higher latitudes.

About half of the energy which comes to Earth from the sun is reflected back into space and lost. The rest of the energy warms the earth. On the average, the earth loses heat at about the same rate as it gains heat. Although there may be slow trends, worldwide average temperatures for land, sea and air do not change much from year to year. During a year there may be large variations due to seasons. And of course the earth is divided into tropic, temperate and polar regions primarily on the basis of temperature. But when yearly averages are figured for the entire earth there is no noticeable trend.

Tropic regions have a surplus of incoming heat. Polar latitudes give up more heat than they absorb from the sun. The information in Figure 6.8 shows average ocean surface temperatures for different latitudes.

Latitude	90°N	75°N	60°N	45°N	30°N	15°N	0°	15°S	30°S	45°S	60°S	75°S	90°S
Average Temperature in °C	0°	5°	8°	12°	21°	28°	28°	26°	18°	12°	6°	3°	0°

Figure 6.8. Average temperature at the surface of the ocean for several latitudes.

PROBLEMS

1. Plot the temperature-latitude information on a graph similar to Figure 6.9.

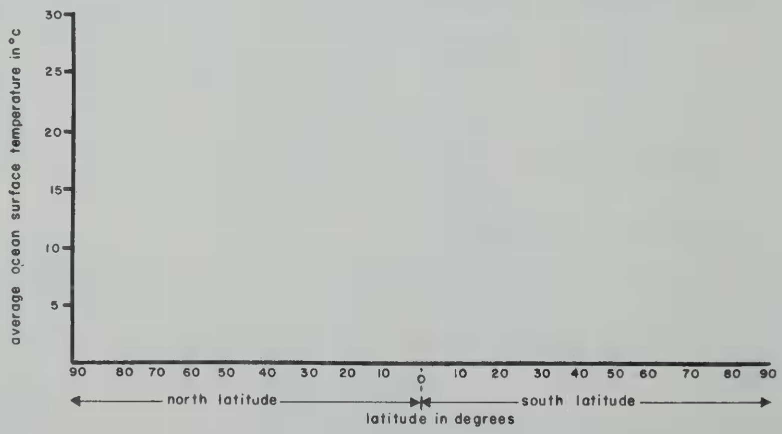


Figure 6.9.

2. Why do latitudes between 15°N and 15°S have the highest average ocean surface temperature?

3. On the basis of temperature, where would you expect the density of ocean water to be (a) greatest? (b) least?

Information about the salinity at several latitudes is given in Figure 6.10.

Latitude	60°	50°	40°	30°	20°	10°	0°	10°	20°	30°	40°	50°	60°
Average % Salinity	3.28	3.31	3.47	3.55	3.54	3.43	3.49	3.53	3.55	3.54	3.50	3.40	3.38

Figure 6.10. Average percent salinity at the surface of the ocean for several latitudes.

4. Study Figure 6.10 and compare salinity and temperature values at various latitudes (see Problem 1). Does the highest salinity occur at the same latitudes as the highest temperature?

5. Problem 4 may help to show you why graphs are often used to compare data. Directly below the graph you prepared for Problem 1, make a graph of the data shown in Figure 6.10. The graph should be similar to Figure 6.11.

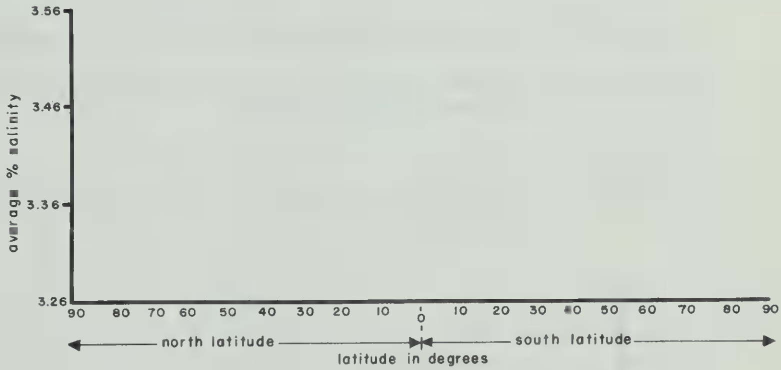


Figure 6.11.

6. Recall the effect that temperature change has on the density of water. Remember, too, the effect of percent salinity on density. Would you expect the density of sea water to be greater at the equator (0° latitude) or at 25° latitude? Give reasons for your answer.

Evaporation, rainfall and temperature changes all affect the density of sea water. When water brought into an area by a current is colder or more salty than the surrounding water, the more dense water will sink. Deep water circulation patterns are controlled by temperature, salinity, and the shape of the ocean basins. Throughout most of the oceans there is a stable arrangement of density layers. This information is indicated by the data in Figure 6.12. At greater depths the temperature is colder and the water is more dense.

Depth in Meters	Average Temperature in $^{\circ}C$
0	21°
250	20°
500	9°
1000	4°

Figure 6.12. Average ocean temperatures at several depths in the temperate region.

7. Plot the temperature-depth information on a graph similar to Figure 6.13.

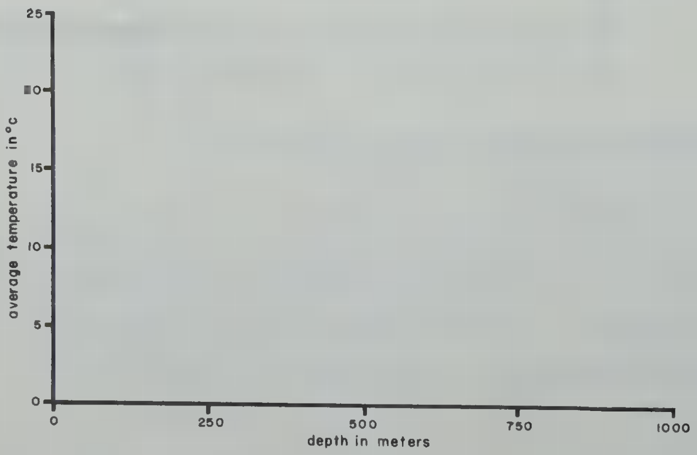


Figure 6.13. Graph for Problem 7.

8. In what range of depth does the most rapid temperature change take place?

9. Why is it reasonable to expect that water will have very little tendency to move upward from the ocean floor?

The tendency of the deep water to remain far below the surface has serious consequences for ocean plants and animals. The phosphates, nitrates and other minerals needed by living things get used up near the surface. Decay of dead things near the bottom makes the water there rich in substances needed for life. Where the wind blows in the proper direction along a coastline, currents can move surface water off shore. The deep water then moves upward to replace the surface water. It brings with it the nutrients that plants and animals need to grow well. The fishing industries in coastal waters off Peru and California take advantage of this condition. The upward movement of deep water brings great economic advantage to locations where it occurs.

TEACHER MATERIAL

CIRCULATION IN THE OCEANS

The concepts learned in the laboratory can be applied to a model for ocean currents. The problems provide data for the development of the model.

PROBLEMS

1. See Figure T-6.3. Caution students to leave space below this graph for Problem 5.

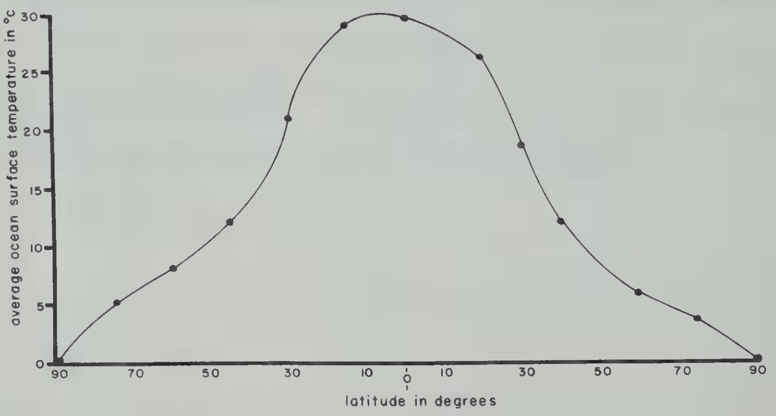


Figure T-6.3. Sample graph for Problem 1.

2. The days are always about 12 hours long near the equator so there is no winter season for cooling off.

3. Density decreases as temperature increases. On the basis of temperature <u>alone</u> the greatest density would be expected at the poles and the smallest at the equator.

4. Careful study of the tables should reveal that the greatest salinity does not occur at the same latitudes as the maximum temperature.

5. By placing the graphs one below the other, the answer to the question asked in Problem 4 should be obvious. This technique should point out one of the advantages of graphic representation.

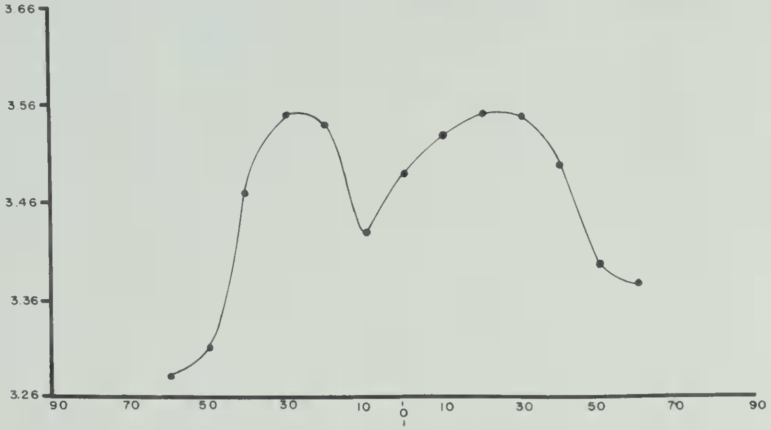


Figure T-6.4. Sample graphs for Problem 5.

6. The density should be greater at 25° latitude than at the equator because higher temperature means lower density and lower salinity means lower density.

7. See Figure T-6.5.

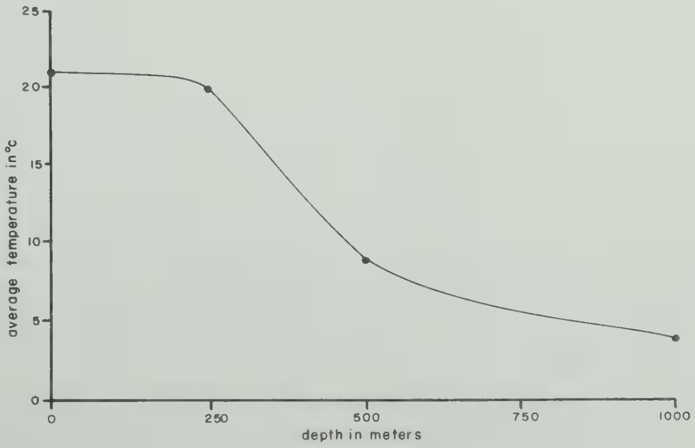


Figure T-6.5. Sample graph for Problem 7.

8. Inspection of the graph shows the steepest slope (and therefore the most rapid rate) occurs between 250 and 500 meters depth.

9. The densest water sinks the lowest, so gravity will act against any force that tends to bring that water upward.

INVESTIGATION 6.5: Gases Dissolved in Water

Plants and animals that live in the ocean need material from above as well as from below. Gases from the atmosphere are as important to sea life as are nutrients from the ocean depths. Green plants need carbon dioxide in order to live and grow. As plants use up carbon dioxide they produce oxygen. Land plants get carbon dioxide from the air and release oxygen into the air. This investigation may help you to understand problems associated with the supply and production of gases by ocean plants.

Materials (per team)

- Indicator solution
- Graduated cylinder
- Jar without lid
- Jar with lid
- Drinking straw

Procedures

A. Obtain 50ml of indicator solution. Pour it into the jar for which there is a lid. Record the color of the solution in your notebook.

B. Put the straw in the solution. Gently blow through the straw until a definite color change is observed. Record the color of the solution.

C. Measure 25ml of the solution used in Procedure B into the second jar. Leave the remainder in the first jar and put a lid on it. Label both jars for identification

and put them in an open area where they will not be disturbed. Leave them there overnight.

Interpretations

1. What are the principal gases present in your lungs?

2. What do you think caused the indicator to change color?

3. Outline an investigation that would test gases to find their effects on the indicator solution.

Procedures (continued)

D. Observe the jars you allowed to stand overnight. Record the color of each solution.

Interpretations

4. Why do you think you were instructed to put a lid on one jar?

5. How can you explain changes in color that occurred overnight?

6. How can the results of this investigation be related to plants growing below the surface of the ocean?

TEACHER MATERIAL

INVESTIGATION 6.5: Gases Dissolved in Water

In this investigation students see that gases can be absorbed into water from the air and that they can be lost again from the solution to the atmosphere.

Materials

Indicator Solution: Stir bromthymol blue powder, a little at a time, into 500ml of water until the solution has a rich color. The color will be either blue, green or yellow depending on the sample of water. Bromthymol blue is an acid-base indicator which is blue in basic, green in neutral, and yellow in acidic solutions. The color change is reversible by adding acid or base to the solution. Add acid (to a blue solution) or base (to a yellow solution), a drop at a time, until the solution is green. The solution is nearly ready when a drop of acid will make the entire solution change to yellow and a couple of drops of base will change it from yellow to blue. Be sure the solution is kept stoppered since it reacts with CO_2 in the air. The color should be green when the students get it.

Base solution to prepare indicator: Add 0.2 grams of sodium hydroxide (Caution--Caustic) to 100ml of water.

Acid solution to prepare indicator: Add 1ml of concentrated hydrochloric acid (Caution--Caustic) to 200ml of water.

Jars: Baby food jars are excellent (and usually free).

Optional materials (if you want to demonstrate answers to some of the interpretations):

Cylinders of oxygen, nitrogen, and carbon dioxide
(or baking soda--sodium bicarbonate)
Dilute hydrochloric acid
Erlenmeyer flask, 250ml
Plastic bags, 1 quart size
Rubber tubing
Mineral oil, 10ml

Procedures

A. The color of the indicator solution should be green.

B. As carbon dioxide from the breath dissolves in the solution it forms carbonic acid. The color will change from green to yellow, probably after one or two deep breaths have been bubbled through the solution.

C. The student samples should not be placed in a cupboard or closet. They need to be exposed to the free movement of air.

Interpretations

1. You may need to discuss with students the answer to this question. The breath contains nitrogen, oxygen and carbon dioxide.

2. At this point the correct answer is not essential, but students may guess that carbon dioxide is responsible.

3. Students should suggest bubbling known samples of gas through the indicator and observing color changes. If cylinders of gas are available, attach the rubber tubing and gently bubble nitrogen, oxygen and finally carbon dioxide through the solution. Only CO_2 will produce a color change.

If cylinders are not available, move a plastic bag through the air to fill it. Tightly hold the mouth of the bag around the tubing and squeeze the bag to force air (nitrogen and oxygen) through the solution (no change). Then flatten the bag. Put baking soda into the erlenmeyer flask and add hydrochloric acid to the flask and hold the mouth of the bag tightly around the top of the flask. Carbon dioxide will be

generated, and if enough soda and acid are used, the bag can be filled. Remove the bag from the flask and put the tubing partly in the bag. Tightly hold the bag around the tubing and squeeze the bag, forcing CO_2 to bubble through the solution. The indicator will turn yellow.

Procedures (continued)

D. The jar that was left open will change color by the next day. The jar with a lid should remain about the same color as it was the day before.

Interpretations

4. The lid prevents CO_2 from escaping into the atmosphere. You may want to repeat Procedures B, C and D, but pour mineral oil on top to prevent gas exchange with the atmosphere. (Do not use vegetable oil because it reacts with the solution.) In a sample test, the yellow color caused by CO_2 persisted for more than two weeks.

5. The color change of the indicator corresponds to a decrease in dissolved CO_2. In the open jar, the CO_2 must have escaped from the solution into the air.

6. This investigation showed that CO_2 can be absorbed from air into water and escape from water into air. It may be absorbed by water in regions where the dissolved supply is depleted by plant growth.

OPTIONAL DEMONSTRATION: The Effect of Temperature on the Solubility of Gases

The purpose of the demonstration is to show that as the temperature of a liquid is increased its ability to absorb gas is decreased. Do not tell students the title, as it may give away the purpose of the demonstration prematurely.

Materials

Erlenmeyer flasks (250ml), 2
Two-hole stoppers to fit flasks, 2
Indicator solution
Hot plate or burner
Thermometer
Glass tubing

Assemble the apparatus as shown in Figure T-6.6.

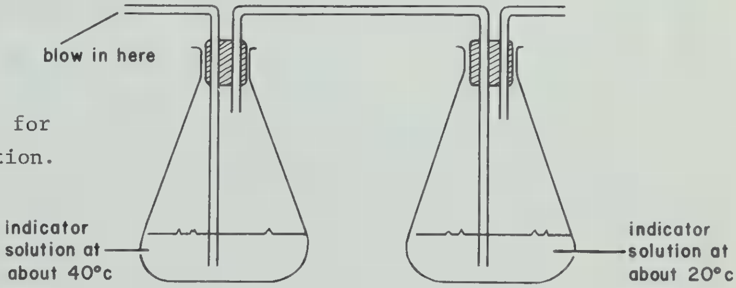


Figure T-6.6. Set up for Demonstration.

Ask students to predict what will happen when you blow into the tubing. (Do not tell them the two flasks are at different temperatures.) Record their predictions on the board. Then blow into the solutions. (The warm solution will remain green while the cool one turns yellow. This is a result of the fact that warm solutions will not absorb as much gas as cold solutions.) Ask students to propose models for what they have observed. Discuss their answers and ask them to support their ideas. Finally let someone examine the apparatus in detail. The temperature difference should be noted. In discussing the effect of temperature on solubility of gases in liquids, point out that atmospheric gases can be expected to dissolve more readily in cold climates than in warm ones.

GASES AND WATER QUALITY

Oxygen is a gas which is essential to living things on Earth. Since we live on dry land and obtain our oxygen from the atmosphere, we tend to think of the atmosphere as being the main reservoir of oxygen for the earth. In reality, vast amounts of oxygen, nitrogen, carbon dioxide and other gases are dissolved in the oceans. (Dissolved oxygen is mixed with water and can easily be removed from it. This is the oxygen which is referred to, not the combined oxygen which makes up the O part of H_2O.)

Most of the oxygen which eventually finds its way into the atmosphere is produced by plants living in the oceans. The gills of fish are adapted for removing dissolved oxygen from water; the lungs of men and other land animals are suited for use of the oxygen in the atmosphere.

Some solids (salt for example) will dissolve in water more easily than will others (such as sulfur). Similarly, some gases will dissolve more easily than will others. Carbon dioxide is extremely soluble. The result is that the oceans serve as a reservoir of carbon dioxide. If for some reason a large amount of carbon dioxide were removed from the atmosphere, it would be replaced by more carbon dioxide coming out from solution in the oceans. Or if an excess of carbon dioxide were produced in the atmosphere, much of it would be absorbed by the oceans. Thus the oceans keep the amounts of gases in the atmosphere more constant than would be the case on a waterless planet.

As your investigations may have shown, an increase in temperature reduces the amount of a gas which can remain dissolved in water. Power plants are often cooled by water, which is heated in the plant and then returned to oceans, rivers or lakes. This raises the temperature of the water locally and reduces the amounts of dissolved oxygen and carbon dioxide. Fish may

not be able to survive the shortage of oxygen. Plants may also die as a result of the carbon dioxide shortage. Although such effects are generally local, an important fact is illustrated: If ocean temperature changes were widespread there would be large-scale changes in the types--and number--of organisms living in the sea. It should be noted that about 70% of the oxygen produced on the earth is made by plants which live in the sea.

Pressure also plays an important part in determining the amount of gas which can be dissolved in water. You may have noticed that when the lid is removed from a bottle of a carbonated soft drink the dissolved carbon dioxide comes out of solution rapidly. The effect is most obvious when the beverage is warm and its ability to hold dissolved gas is low.

Pressures are greater at greater depths in the ocean. Therefore more of the gases, such as oxygen and carbon dioxide can be dissolved in water deep below the surface. It would then appear that plants and animals, which depend upon the dissolved gases, should be more numerous deep in the oceans than near the surface.

But this is not what actually happens. Much of the life in the oceans is found close to the ocean surface. Sunlight will only penetrate to depths of a few meters beneath the surface. Therefore plants which depend upon sunlight for their energy are common only in the upper levels of the ocean. Sea animals which depend upon plants for their food are, in turn, restricted to the upper levels of the ocean.

Even if light could penetrate to great depths it is unlikely that plants could survive very far from the ocean surface. Actively growing plants require much carbon dioxide and produce much oxygen. At the surface of the sea these gases enter and leave the areas in which plant life is active. Waves which ruffle the surface of the ocean increase the amount of water

which is in contact with the atmosphere. The result is that exchange of gases can take place very rapidly near the surface and only very slowly in the undisturbed, deeper parts of oceans. Near shorelines, where breaking waves are common, gas exchange between ocean and atmosphere is most rapid.

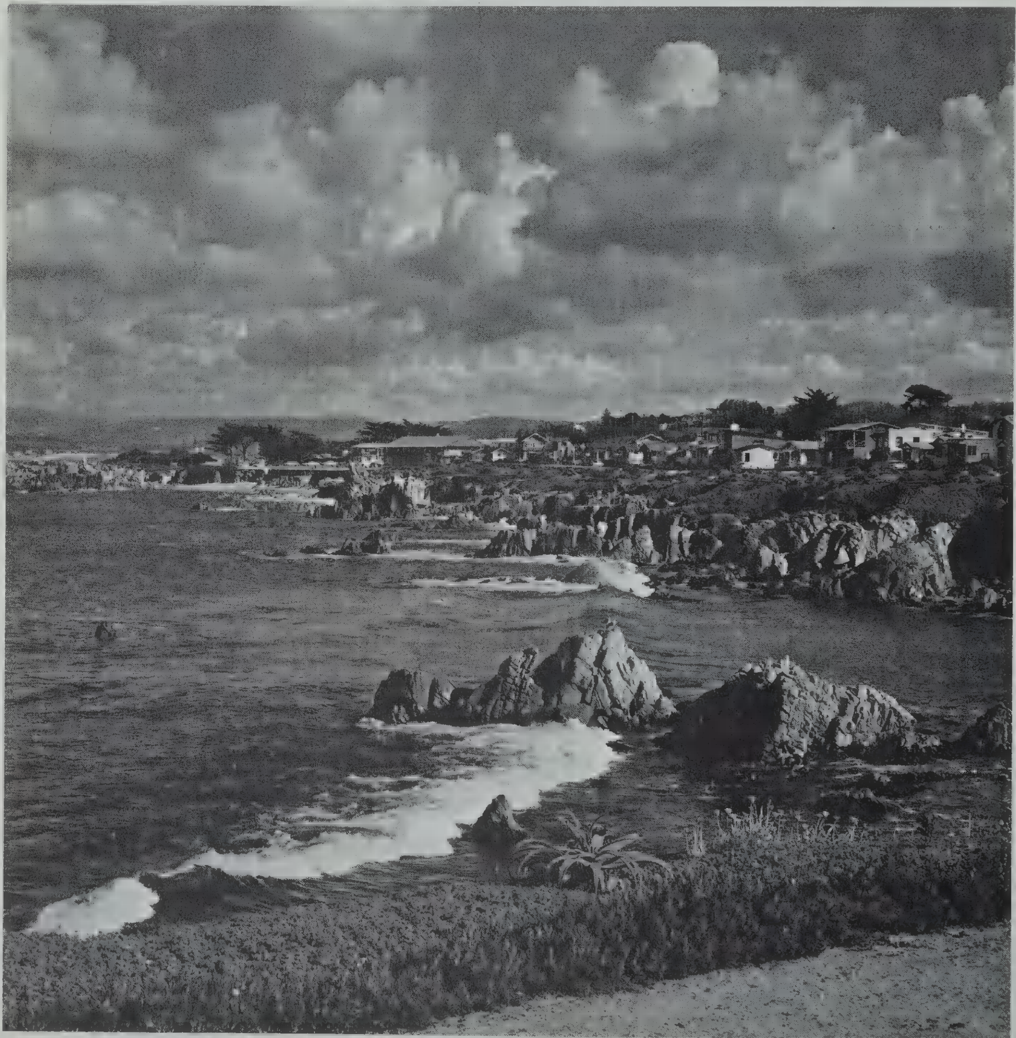


Figure 6.14. The Pacific coast.

Spillways around dams cause much turbulence (churning) in the water going through them. This should provide a plentiful supply of oxygen for migrating fish. But too much of a good thing can have disastrous effects. In addition to the extra oxygen churned into the water, large amounts of nitrogen are dissolved from the atmosphere. This excess of nitrogen, which is normally not very soluble, can kill certain types of fish. The effect is somewhat similar to "nitrogen narcosis," a problem facing scuba divers who breathe high concentrations of nitrogen when diving at depth.

The delicate balance of gases necessary for life in lakes, rivers and oceans is sometimes upset by the dumping of sewage. Sewage contains materials which serve as nutrients (food) for certain types of bacteria. These bacteria can increase in numbers very rapidly when conditions are right. With the addition of sewage to waters, enormous numbers of bacteria are able to develop in a very short time. These bacteria use oxygen which they obtain from the water. There may be insufficient oxygen left for fish and other larger forms of life, and these in turn die. Even if the bacteria themselves die off, it may take years for conditions to again reach the proper balance for the larger types of life to return.

Gases can be exchanged with the atmosphere only at the surface of a body of water. Nutrients are brought up from the depths by upwelling water. Thus a knowledge of the depth of a body of water is essential to understanding life processes in it. In the next investigations you will consider methods for finding the depth of a body of water.

OPTIONAL INVESTIGATION: Water Samples From Beneath the Surface

Preceding investigations have made students aware of changes in water temperature, density, salinity and so forth with changes in depth. Oceanographers wishing to determine the properties of water at varying depths are sometimes able to obtain their data by means of instruments which can be lowered from a ship. At other times it is necessary for them to obtain actual samples of water from some particular level.

A typical container designed for this purpose consists of a metal "bottle" which is lowered to a pre-determined depth on a weighted cable. A "messenger" weight is then slid down the cable. This causes the bottle to open, fill and be capped. The sample is then retrieved.

In this investigation students should be challenged to develop a device which will obtain a water sample from beneath the surface.

Materials

- String
- Thread
- Weights
- Vials or test tubes
- Gallon cans filled with water
- Tape
- Paper clips
- Etc.

Procedures

A. Explain the purpose of the investigation to students but do not describe devices which are conventionally used for the purpose. In practice, sampling bottles must be closed until lowered to the depth at which the sample is to be procured. Air trapped in an inverted, open container will not exert sufficient pressure to exclude water from entering the bottle before it reaches the desired depth. The bottle should also be recapped after the sample is taken to prevent mixing of the sample with water from lesser depths as it is retrieved. Such refinements are probably not necessary for the shallow depths in which student devices will operate.

B. Provide students with materials and allow each team to build its own water-sampling device.

C. Allow each team to describe and demonstrate the device it has constructed. Call for suggested improvements to devices and encourage students to continue development on their own.

INVESTIGATION 6.6: Probing the Depths

Have you ever wondered what the bottom of a nearby lake looks like? If you spend much time fishing in the lake you may find it worthwhile to know where the deep parts and shallow parts are. If you were a ship's captain, knowledge of shallow areas along ocean routes would be very important. In this investigation you will be challenged to determine what the bottom of a container "looks like" without actually seeing it.

Materials (per team)

- One gallon can of liquid of unknown depth
- Lead weight, 1/2 oz.
- String
- Glass tubing, 6mm O.D.
- Ruler
- Wire screen, 1/2" mesh 8" x 8"
- Graph paper, 1/2" grid
- Masking tape
- Paper clips
- Toothpick

Procedures

A. Obtain a numbered can from your teacher. Be careful not to spill any of the liquid from the can. Record the number of the container in your notebook. Place the can on the center of a piece of graph paper and trace its outline on the paper. Mark the outline north, south, east and west as shown in Figure 6.15.

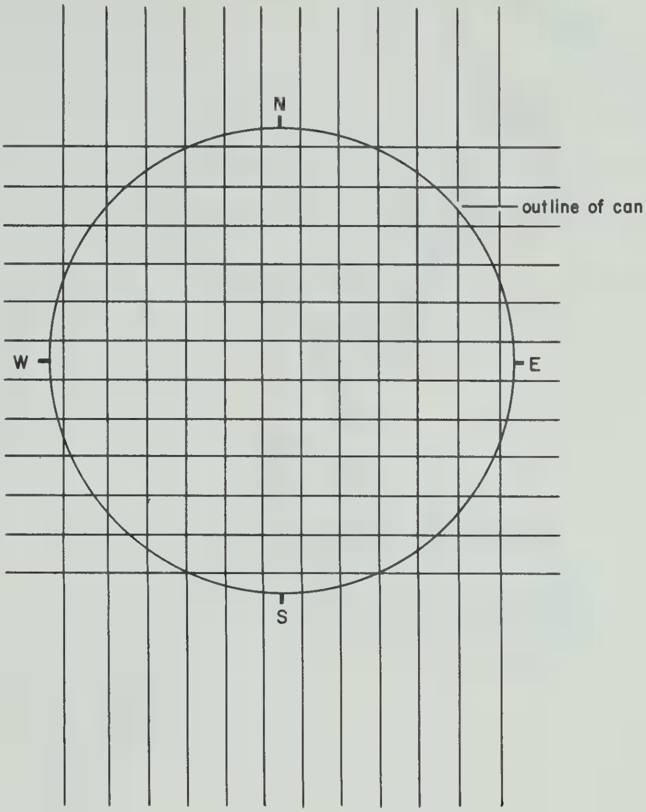


Figure 6.15.

B. Cut a piece of glass tubing the length of your ruler. Tape the tubing to the ruler as shown in Figure 6.16.

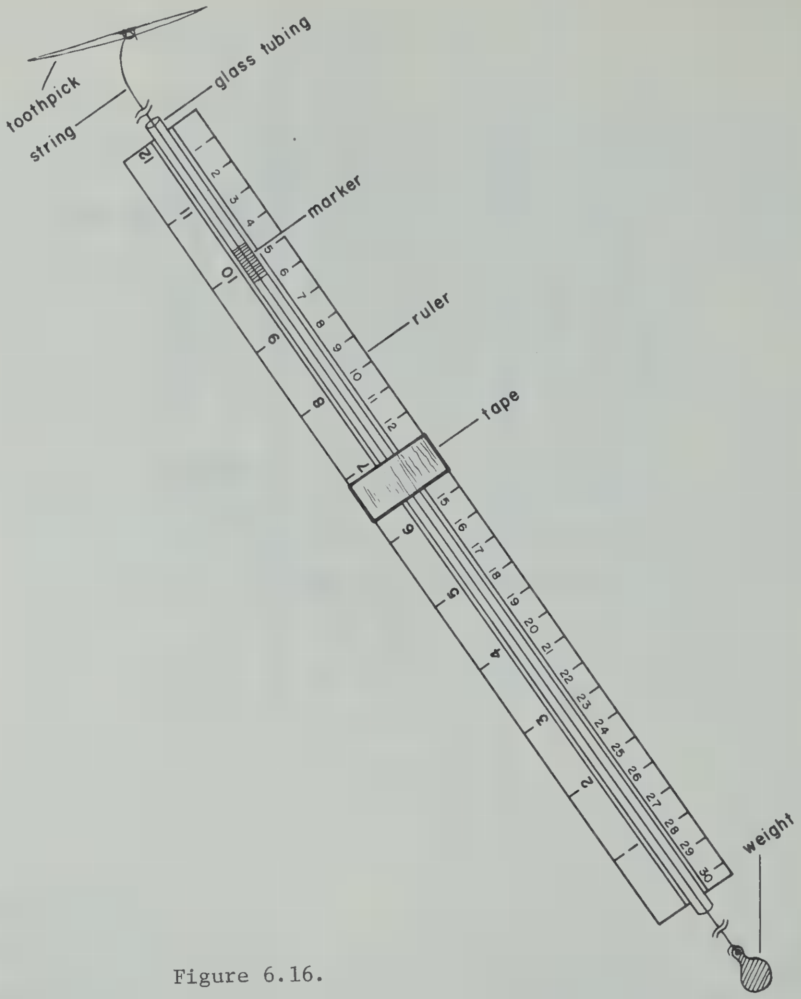


Figure 6.16.

C. Center the piece of wire screen over the top of the can. Turn the can so the seam is facing you. Hang a paper clip on a segment of wire next to the seam. Mark a small piece of masking tape with the letter "S" and stick it to the paper clip. Now the seam of the can represents direction "south." Hang labeled paper clips to represent "north," "east" and "west" (Figure 6.17). In addition to indicating direction, the paper clips also are used as guides in keeping the wire grid centered over the can.

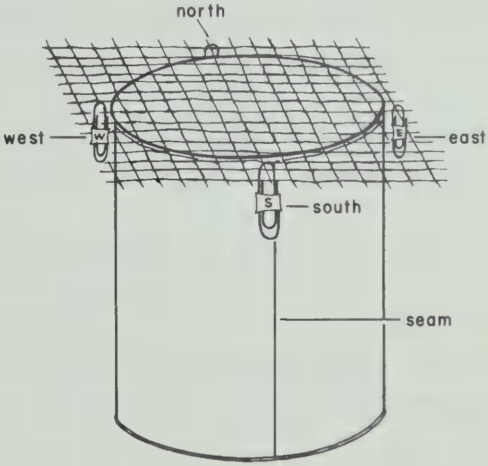


Figure 6.17.

D. Cut a piece of string about 50cm long. Tie one end to the weight, thread the string through the tubing, and tie the other end of the string to the toothpick. (Be sure the toothpick is tied to the string at the <u>low</u> end of the <u>centimeter</u> scale of the ruler.) Hold the ruler vertical and allow it to rest on the wire screen. Lower the weight until it just touches the surface of the liquid. Wrap a <u>small</u> piece of tape around the string with its lower edge even with the zero mark on the ruler.

E. Place the depth finder over the square nearest the "north" marker. Lower the weight until it touches bottom. Read the number on the ruler indicated by the bottom of the tape marker on the string. Record the value in the corresponding square on the graph paper. Continue probing in all the squares in the "north-south" row and record your readings. Obtain values for the "east-west" row of squares.

Interpretations

1. Draw one profile of what you think the bottom looks like along the "east-west" line and a separate profile for the "north-south" line.

2. How far below the surface of the water is the deepest point in the container? The shallowest?

3. Do you think you have an accurate idea of the bottom of the can? If not, what could you do to improve your idea?

4. What limitations would this method of depth finding have in larger bodies of water?

INVESTIGATION 6.6: Probing the Depths

The investigation shows students how a knowledge of the profile of the bottom of a water body can be built up through systematic observations.

Materials (for six teams)

The containers should be one-gallon tin cans prepared and numbered the day before student use to allow the bottoms to "set-up." To prepare the cans, add plaster of Paris to about 500ml water until a medium paste is obtained. Tilt the cans by placing one edge on a board or object about two inches high. Divide the paste evenly between the cans to form a slant in each. See Figure T-6.7.

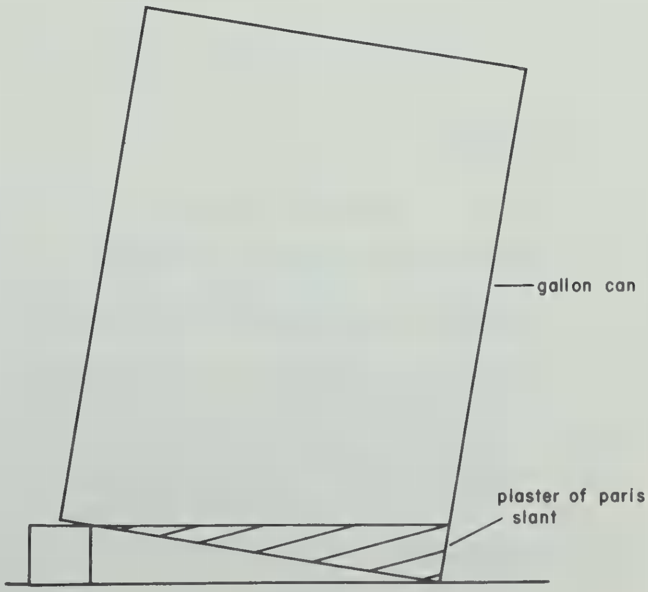


Figure T-6.7.

The steepness of the slant may, of course, be varied to suit your particular needs. When the slants have hardened, prepare another paste, reverse the cans, and pour an opposing slant to form a "V" in the bottom of the can. A third, smaller slant, can be poured at one end of the "V" to form a "Y." The complexity of the bottom configuration may be varied to suit student abilities. Since students will use the seam as a reference point, the slants in different cans should be poured in varying positions relative to the seam. The plaster of Paris will not dissolve when covered with water, but the slants may become disloged with rough handling especially after prolonged soaking. This, however, permits reuse of the containers. If more permanent slants are desired, ready-mix cement may be substituted for plaster of Paris.

You will need about three pounds of plaster of Paris to prepare six cans.

Lead fishing weights small enough to fit through the wire mesh can be purchased at local sporting goods stores.

The wire screen (hardware cloth) may be purchased locally and cut into 8" x 8" squares. The sharp edges may be bent over or covered with tape to prevent cuts.

An opaque solution to "hide" the bottom can be prepared by adding non-fat powdered milk to water in the cans.

Procedures

A. Make it clear to students that good data and logical interpretations are the goals of this investigation (as is the case in all investigations), not an exact answer. They should not reach into the can or pour out the milk-water, but accept the challenge to indirectly "look" at the bottom.

B. You may want to precut and fire-polish the tubing.

C.-D. No comment.

E. See sample response, Figure T-6.8.

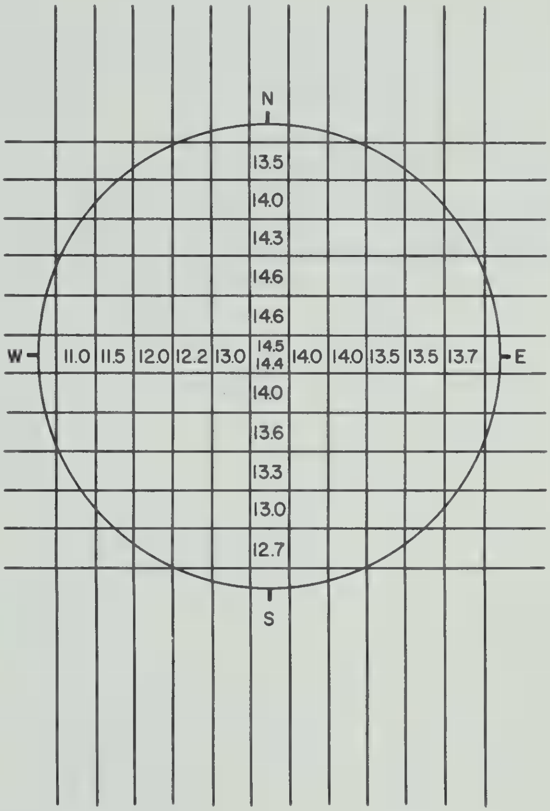


Figure T-6.8.

Interpretations

1.-2. Answers will depend on your pouring pattern.

3. The relatively small number of probes leaves more area of the bottom unsampled than sampled. Improving the profile would require more probing. Encourage interested students to continue probing until a complete record is obtained. This activity also offers a clear-cut example of model building and improvement which you may want to discuss with the class.

4. Line and weight sounding is not practical for large deep bodies of water and it is comparatively slow. A description of an actual sounding program is given in the student text.

OCEAN SOUNDING

The first organized study of the ocean floor was started by the British Ship "Challenger," in the 1870's. A four mile long cable with a weight at one end was used to measure depth. More than 360 measurements were made, but the accuracy left much to be desired. Ocean currents caused the cable to curve, making the depth seem greater than it actually was. The amount of stretch in the cable depended upon the length used, the temperature, ocean currents and other factors. But depth was measured according to marks on the cable. Perhaps you can imagine the similar difficulty you would have using a ruler printed on a rubber band.

TEACHER MATERIAL

INQUIRY DEMONSTRATION: Bouncing-Ball "Sonar"

This demonstration is designed to familiarize students with the principles of SONAR as used to determine ocean floor profiles.

Materials

"Super Ball," 1 1/2" diameter
Concrete building blocks, 7 1/2" x 7 1/2" (9)
Large cardboard carton
Butcher paper (optional)

Procedures

Before students enter the room, stack the blocks on the floor behind your desk or demonstration table. If such a shield is not available, you will have to construct a screen of butcher paper taped to chair backs or other uprights. The blocks should not be in view of any students in the room. Keep the blocks hidden from entering students by covering the stack with an inverted carton, until you are ready to begin the demonstration.

A. After the students are seated, uncover the blocks and quietly arrange them into stacks as shown under Profile 1, Figure T-6.9. The nature of the blocks and their arrangement should not be disclosed to the class.

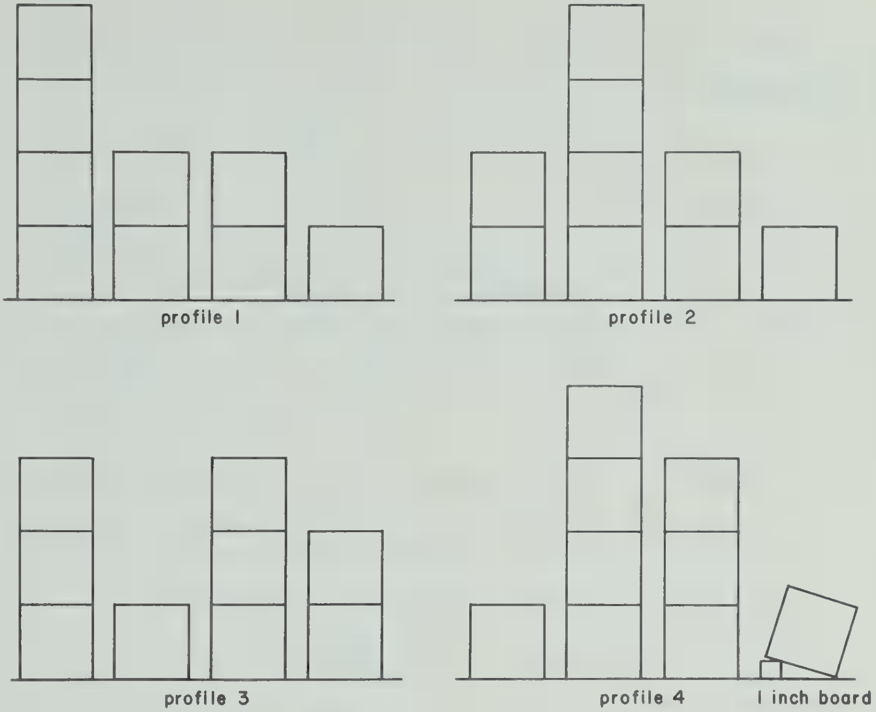


Figure T-6.9.

B. Ask students to make observations as you drop the Super Ball several times to the floor and catch the rebound. Drop the ball from about the same height (preferably from just above your head) each time.

C. Ask students to describe briefly what they saw. (One possible observation here is that the ball bounces up to the same height each time. Do not prolong this discussion.)

D. Now drop the ball several times so it bounces from the top of the two-block stack. Ask for a comparison of the first set of drops and this set. (Students are likely to say the sound was different between the two sets of drops. The bounce is about the same height for

both sets. If no other comparisons are made, drop the ball again on floor and blocks and press for other observations.)

E. If no one suggests it, ask if they think the ball in the second set of drops is bouncing off something above floor level. If so, how far above floor level? If after some discussion the majority of the class cannot make a judgment, you may tell them the height of the blocks and verify this for the class by dropping the ball on floor and blocks several more times.

F. Engage the class in a discussion of exactly what observations are necessary to determine the height of the rebounding surface. Many students who are able to distinguish between heights may not be able to verbalize the clues that enable them to make the distinction. One way heights may be determined is by comparing the <u>time</u> it takes between the visual disappearance of the ball and sound of the bounce from differing heights.

G. Ask students to draw a straight line across the bottom of a piece of paper. The line is a reference and represents the floor level. A second line near the top of the paper is a reference representing the top of the demonstration table or butcher paper screen. The students are to draw short horizontal lines between the reference lines to indicate <u>relative</u> heights and positions of bounce surfaces as you drop the ball on each stack.

H. Drop the ball several times on each stack. Assign each stack a number as you do this. You may need to drop the ball on the floor occasionally to refresh student minds. Allow students to suggest drop patterns to help them make their judgments.

I. You may then want to divulge the stack profile to reinforce their work. Change the profile two or three times and allow them to draw the new height patterns. Some possible profiles are shown in Figure T-6.9, Profiles 2, 3 and 4.

SONAR

In 1922 a new method for measuring ocean depths was developed. Sound waves can be reflected from the bottom of the ocean. By measuring the time it takes sound waves to go from a boat to the ocean floor and bounce back, the distance can be calculated. Sonar is the name of this system. The name comes from an abbreviation of <u>so</u>und <u>n</u>avigation <u>a</u>nd <u>r</u>anging (ranging means measuring distance). During World War II sonar was improved. It was used for navigation and for detecting submarines. It is now a standard navigational tool and is useful to the fishing fleets for locating schools of fish.

In sea water, sound travels at about 1460 meters per second (nearly a mile per second). Because of the great speed, this method is as quick as it is convenient. A continuous profile along the ocean floor has been made for many locations. Maps constructed from such data have been used by geologists to develop theories about the way the earth's surface is changing.

PROBLEMS

1. Figure 6.18 provides information about the depth of the Atlantic Ocean along latitude 39°N. The depth measurements begin on the coast of New Jersey and go straight across the Atlantic to Portugal.

   Draw a line across the top of a sheet of graph paper and label the line "sea level." Use the data in Figure 6.18 to make a profile map (side view) of the ocean floor along 39°N latitude.

Distance from New Jersey in Kilometers	0	160	200	500	800	1050
Depth of Ocean Floor in Meters	0	165	1800	3500	4600	5450
Distance from New Jersey in Kilometers	1450	1800	2000	2300	2400	2600
Depth of Ocean Floor in Meters	5100	5300	5600	4750	3500	3100
Distance from New Jersey in Kilometers	3000	3200	3450	3550	3600	3700
Depth of Ocean Floor in Meters	4300	3900	3400	2100	1330	1275
Distance from New Jersey in Kilometers	3950	4000	4100	4350	4500	5000
Depth of Ocean Floor in Meters	1000	0	1800	3650	5100	5000
Distance from New Jersey in Kilometers	5300	5450	5500	5600	5650	
Depth of Ocean Floor in Meters	4200	1800	920	180	0	

Figure 6.18. Sonar measurements of the depth of the ocean floor along latitude 39°N from New Jersey to Portugal.

2. If all the water were removed from the Atlantic Ocean, how would you describe the feature occurring between 2000 kilometers and 4500 kilometers east of New Jersey?

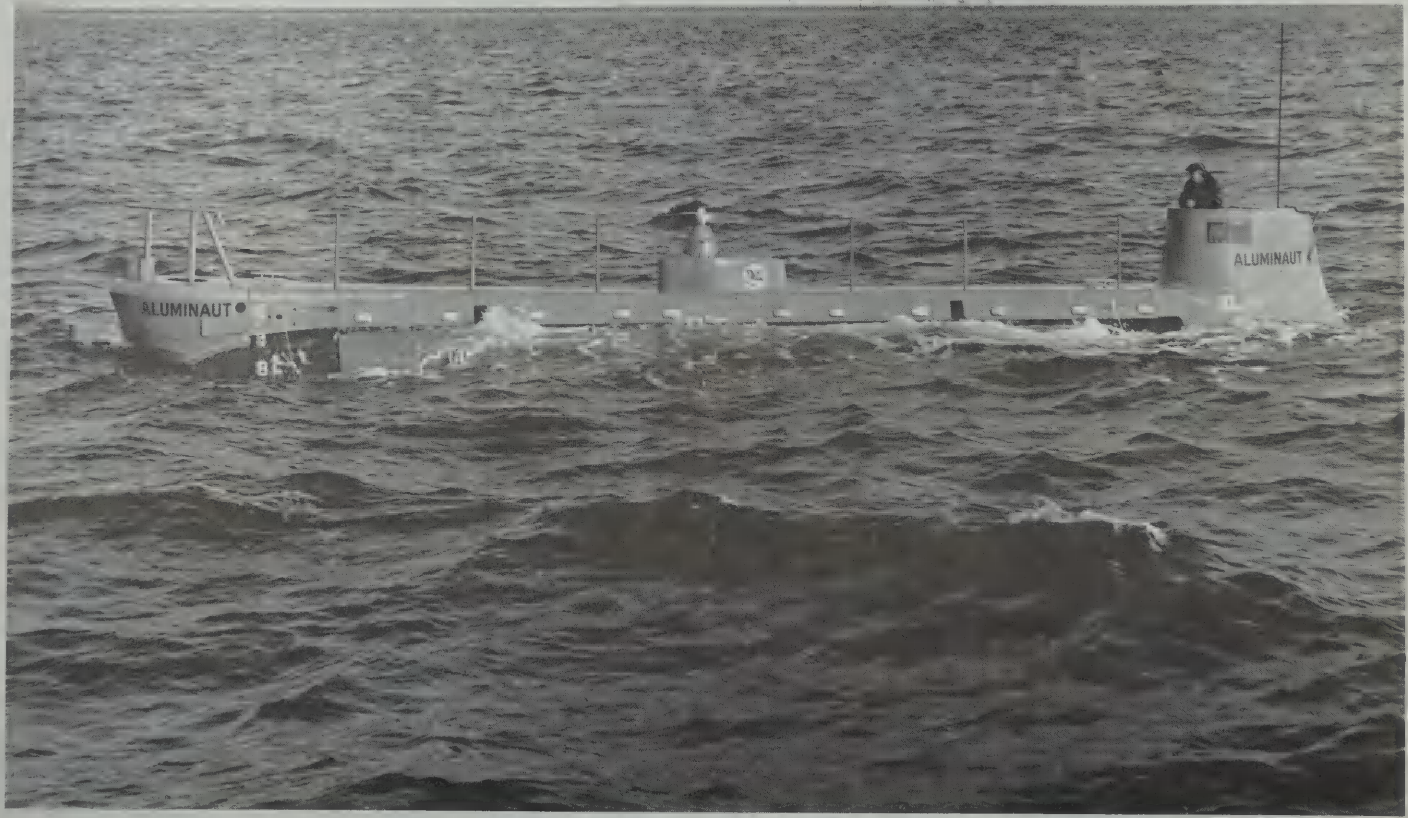
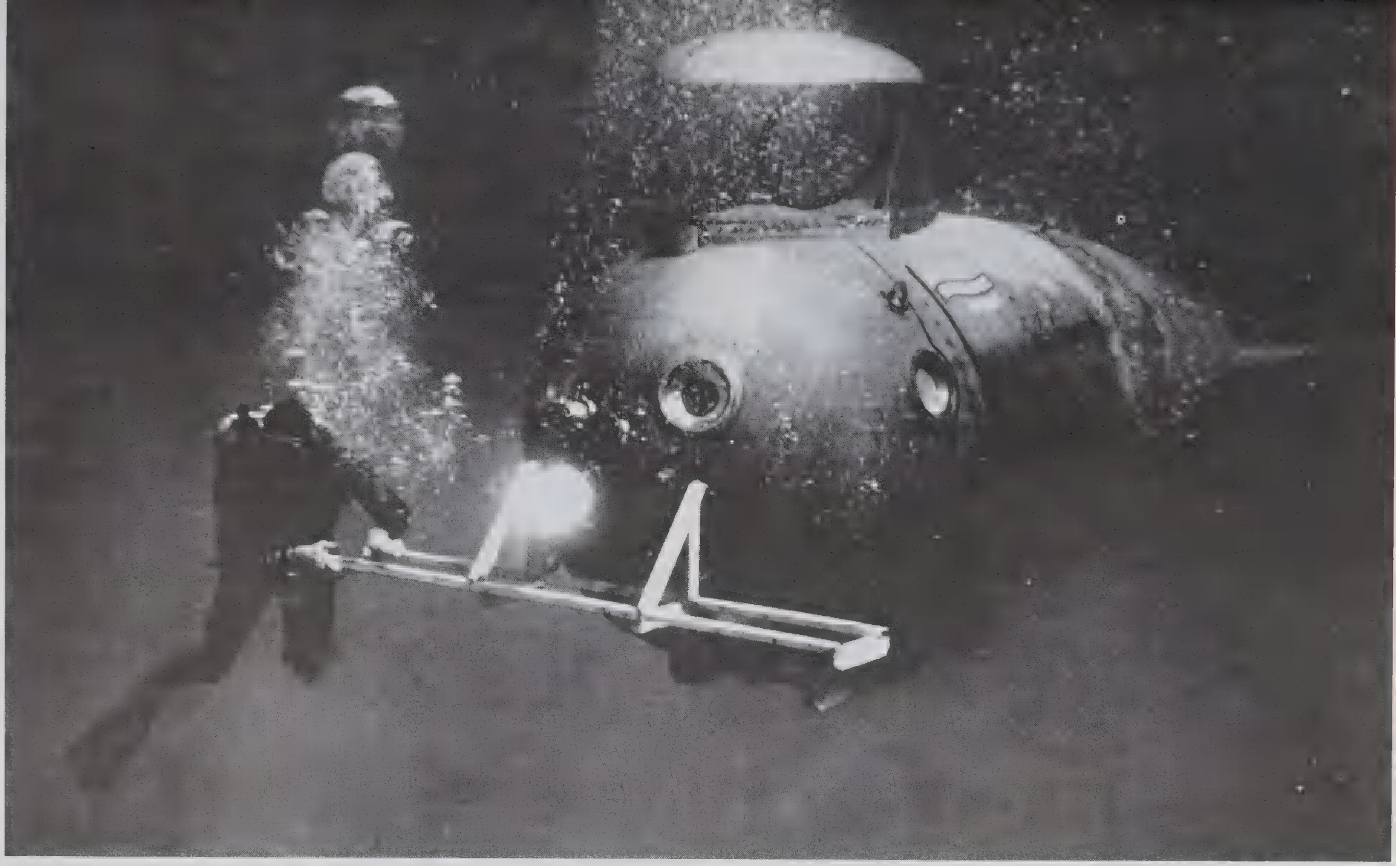


Figure 6.19. Exploring the seas. a) Aluminaut, 54 feet long, is the world's first all-aluminum submarine. Designed for ocean research, it has gone to a depth of 6200 feet.



b) Asherah, used by the University of Pennsylvania, was designed for underwater archaelogical research. Others, such as the Bureau of Fisheries, have found many different uses for this small research vessel. Can you suggest other possible uses?

c) The U. S. Navy Sealab, before its use in the Pacific waters off Long Beach, California.

In this section you have investigated some of the properties of water. As often happens, the ideas in this area have led to problems in other fields.

Ocean currents are caused by prevailing winds, but what causes the wind?

What effect does the heat stored and transported by the ocean have on weather?

Evaporation changes the salinity of sea water, but what are the geologic effects of the evaporated water?

The oceans are a very ancient feature of the earth--what details of the earth's history are provided by the oceans?

How is the structure of the ocean floor related to such things as earthquakes, mountain ranges, and the shapes of continents?

These are some of the questions that will be considered in the sections that follow.

TEACHER MATERIAL

PROBLEMS

1. See Figure T-6.10.

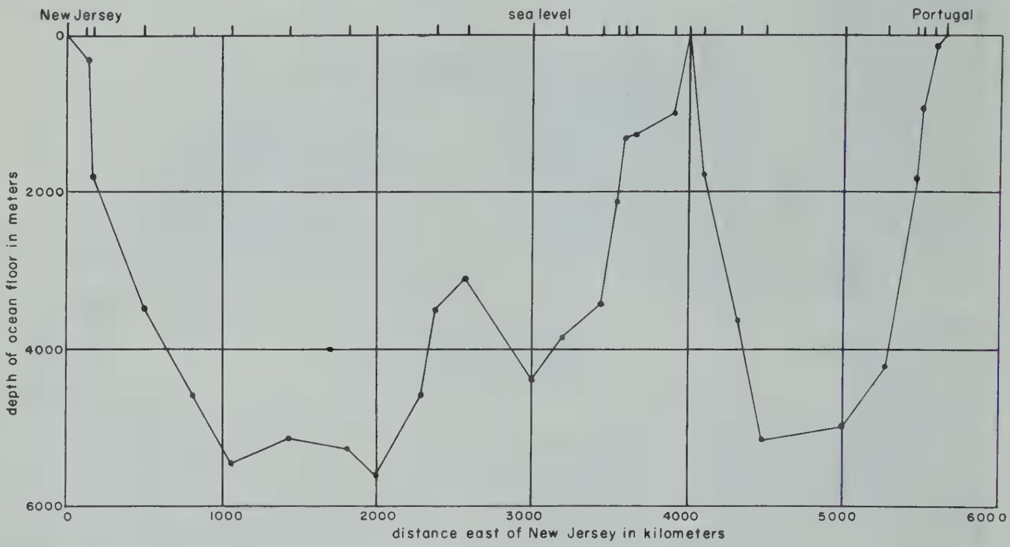


Figure T-6.10. Sample graph for Problem 1.

2. The feature looks like a mountain range. It is part of the Mid-Atlantic Ridge, a mountain range which extends from Iceland almost to Antarctica.

Section Seven:

Time and Change

PREVIEW

Major ideas of the section are the immensity of geologic time, the ways by which evidence of past life has been preserved, changes in life forms through time, the geologic time scale, the mechanism through which changes in life forms have occurred, and the implications of such changes for man as a species.

The section opens with a student investigation involving estimation of short time intervals. Longer time intervals are more difficult to comprehend, so a model for longer time intervals is developed. In it, time intervals are considered analagous to the thickness of a geologic "diary."

Fossils and the differences between fossilized life forms and present-day types are considered in two short reading selections. The geologic time scale is introduced, and in an activity (Investigation 7.2) students plot characteristic life forms in their appropriate places on the scale.

Then a model for changes in life forms is introduced. It consists of thinking of four repeated steps: overpopulation, variation, testing, and survival.

An optional inquiry demonstration uses drosophila to illustrate the tremendous reproductive capacity of some species. NOTE: If you plan to perform this inquiry demonstration please refer now to pp. 177c et. seq.

Examples are given of life forms which have apparently changed through time, and the model for change is applied. Students then calculate the rates at which change must occur in order to produce the observed results in the fossil record.

Certain fossil species are shown to be indicative of characteristic climatic conditions in the past, the nature of the recent ice ages is considered, and the section closes with a suggestion of man's growing ability to cause major changes in the environment.

Section Seven:

Time and Change

You have already studied many changes that occur in your environment--day changes to night, night to day; spring to summer, fall to winter. As the seasons pass daily temperatures change, as do star positions, moon phases and the amount of rain. The living things around you change. Leaves turn brown and fall from trees, grass "dies " birds migrate north and south to find suitable nesting grounds. You are also changing. You are probably getting taller and gaining weight. Each day millions of cells in your body die and are replaced by new cells. People born in the beginning of this century have witnessed an incredible amount of change in the way people live, work, and amuse themselves. You can probably think of many more examples of change that are important to your daily lives.

In nature, change is the rule not the exception. It would be impossible for anyone to describe something about the earth that is not in a state of change. Everything is changing. Some changes take place very slowly and are difficult to detect. In fact some changes take place so slowly that an entire lifetime could be spent trying to detect them. For example the speed of the earth's rotation slows down by a very small fraction of a second in a century.

But an "entire lifetime" is not really a very long time compared to the length of time that the earth has existed. What is a long time--a thousand years, ten thousand years, a million years? What is a short time--a minute, a half a minute, a second, a tenth of a second?

To understand some kinds of change you must first develop a model of time. In the following investigation you will have an opportunity to develop a way of thinking (a model) about time that should help you understand the changes in the plants and animals that have lived on Earth in its long history.

INVESTIGATION 7.1: Constructing a Model for Time

In your everyday life you use many different units of time. These time units include seconds, minutes, weeks, and years. In thinking about changes of the earth and changes in things that live on Earth these units may be too short. You will have to think in terms of thousands, millions and billions of years. These are difficult time intervals to understand. You have more experience with how long a second or a minute is, than with the length of a century. In this investigation you will start by estimating familiar units of time and then develop a model for larger units.

Materials (per team)

Metric rule
Timer

Procedures

A. Construct a chart in your notebook similar to that in Figure 7.1.

Trial	A 10 seconds	B 1 minute	C 10 seconds counting	D 1 minute counting
1				
2				
3				

Figure 7.1.

B. When your teacher says "Start" close your eyes. Try to estimate ten seconds. When you think ten seconds have gone by open your eyes and look at the time. Record the actual time in column A of the table. Repeat the time estimating process twice and record the actual times in column A.

C. Using the same procedure, try to estimate an interval of one minute. Do this three times and enter the results in column B of your table.

D. Watch the timer. Count seconds to yourself, saying, "chimpanzee one, chimpanzee two, etc." Try to establish a rhythm. Do not count out loud or make any movements which might influence those around you. At the end of the practice interval try again to estimate ten seconds. This time count to yourself. Do this three times and enter your results in column C.

E. Try to estimate a minute. Use silent counting to help you. Make three trials and enter your results in column D.

Interpretations

1. What is the longest time interval you can estimate with confidence in your accuracy? The shortest?

Procedures (continued)

F. Use a centimeter rule to measure the thickness of 100 sheets of paper. Measure to the nearest millimeter. You can save some effort by using the numbered pages of a book. Record your answer in your notebook.

Imagine that someone has been keeping a diary of important happenings on our planet. He uses one sheet of paper for each year. As he finishes each year he puts the sheet on top of a stack. If the diary had been started when the earth was formed there would now be a very thick stack of paper. You will now calculate how far down in the stack you would have to look in order to find records of certain events.

Interpretations

2. The Revolutionary War occurred about 200 years ago. How far down in the stack would this event be recorded? (Multiply the thickness of one hundred sheets by 2.)

3. Columbus came to America about 500 years ago. How far down in the stack would this event be recorded?

4. Christ was born about 2000 years ago. How far down in the stack would this event be recorded?

5. Cro-Magnon man was living about 30,000 years ago. How deep in the stack would his records be found?

As you look further back in time you will find that the thickness of 100 sheets becomes difficult to work with. You will need thicknesses representing larger amounts of time. A meter is 1000 times longer than a millimeter. Therefore a meter of thickness will represent 1000 times the time interval represented by a millimeter. The thickness of 100 sheets is a certain number of millimeters. That same number of meters will represent 1000 x 100 years, or 100,000 years.

Interpretations

6. What thickness of sheets of paper would represent 100,000 years?

7. What thickness of sheets of paper would represent 10,000,000 (ten million) years?

Sometimes it is more useful to talk about a geographical region than about one particular place. People may speak of "Asia" or the "east coast" or "western Canada." These are not very exact terms. It is not always necessary to be specific. Sometimes it is simply not possible to be specific. In a similar way it may be desirable to talk about "regions" in time. "Regions" in time are more properly spoken of as "eras." People of today live in one of these eras, the Cenozoic [sen-o-zo-ik] Era. It began about 70,000,000 years ago. You can multiply the thickness that represents 10,000,000 years by 7 to find the corresponding depth in the stack.

Interpretations

8. At what depth in the stack would information about the beginning of the Cenozoic Era be found?

The height of a stack of paper representing time since the beginning of the Cenozoic Era is about as high as the highest mountains on Earth.

Interpretations

9. It might be useful to think of the stack as if it were laid on its side. Name a place which is about as far from your school room as the distance you found for Interpretation 8. (Hint: There are about 1600 meters in a mile.)

The next older time era is the Mesozoic [mez-o-zo-ik] Era. The Mesozoic Era began about 225 million years ago.

Interpretations

10. At what depth in the stack would information about the beginning of the Mesozoic Era be found?

11. Name a place which is about this distance from your school room.

The oldest era you will be concerned with is the Paleozoic Era. The Paleozoic [pay-lee-o-zo-ik] Era began about 600 million years ago.

Interpretations

12. At what depth in the stack would information about the beginning of the Paleozoic Era be found?

13. Name a place which is about this distance from your school room.

Problems

1. In the first part of this investigation you considered seconds and minutes. In the second part you had to think about hundreds, thousands and millions of years. Why was the first part easier?

2. Investigators in Europe have conducted experiments in living in deep caves. A person lives in a cave with food, lights, books, records and other things he may want. He has no clock, radio, television or other device that would give him clues as to what time it is on the surface. Under these conditions how well would you be able to estimate when a day had gone by? A week? A month?

INVESTIGATION 7.1: Constructing a Model for Time

Materials

In addition to the centimeter rules for the class you should have one meter stick available for demonstrating and suggesting the larger distances. A road map of the area may be useful.

Procedures

A. No comment.

B. If you have a large timer place it where it can be seen by all. You may wish to leave it running, allowing students to start intervals whenever they are ready. Alternatively you may wish to start them all together. Caution the class against exclamations which would give clues to those still waiting out an interval.

Lacking a large timer, you can improvise one in the following manner: Place numbers on the chalkboard. For timing the ten-second intervals numbers 1-15 should be sufficient. Refer to your own watch and point to the numbers in turn. Upon opening their eyes at the end of an estimated ten seconds, students record the number to which you are pointing. For the one-minute interval the numbers 20, 25, 30 . . . 75, 80. will give sufficient accuracy and probably cover most estimates.

There is a tendency to underestimate intervals. On their first attempts many students will guess that ten seconds have elapsed after only a few seconds have actually gone by.

C. Again, most people will underestimate on their first attempts, some by a good margin. If you notice that students are counting to themselves, checking pulse rates (this is the method Galileo used), etc. tell them that this is to be done in a later part of the investigation. Students should try to think of "nothing" during the intervals.

D. In order to avoid breaking the rhythm it may be better to "think" the numbers 1 - 10 six times in counting to sixty. This eliminates the problem of polysyllabic numbers such as twenty-seven.

E. No comment.

Interpretations

1. In most cases counting will markedly improve a person's ability to estimate short time durations. Of course, it must be recognized that a second variable, that of practice, is also affecting results. An interested student could make a good project out of extensions of this investigation, testing family and friends on their abilities to estimate durations, then tabulating, graphing and displaying results.

On your next quiz you might wish to include an item of this nature. Tell the students what they are to do, then say, "Start . . . stop." You might separate the two commands by, say, eight seconds and count any answer between 7 and 9 as correct. You would follow this with a second question involving an interval which you measure with your watch as 25 seconds. If you are not certain as to what error to allow, simply tell the students you will give them some leeway and then inspect the papers before deciding the tolerance. Many students will be able to estimate 25 seconds as something between 20 and 27 seconds, particularly those who have thought to use silent counting. A different twist involves estimating a short time interval. Hold an object such as a marble (which will make a distinct noise upon hitting the floor or desk top) a measured four feet above the floor. Have the class estimate the length of time required for it to fall. If you repeat the drop several times, and particularly if you use a countdown to allow a rhythm to be established, students should be able to recognize that about one-half second is taken for the object to fall. (The dependability of gravity ensures that a reasonably dense object will drop from a height of one foot in 1/4 second, from four feet in 1/2 second, and from nine feet in 3/4 seconds.) As a variation you could drop the object several times from a height of four feet BEFORE this investigation is started. Estimates of the time it is taking to fall frequently run as short as 1/100 second. After the counting procedure has been introduced it should be apparent that a more sizeable fraction of a second is involved.

<u>Procedures</u> (continued)

F. The paper these books are printed on gives a value of about 10mm per 100 sheets. Do not worry

about loss of accuracy involved in rounding off. We are more concerned here with rough distances than with precision. You may want to use an average value for the class or let each student keep his own value.

Interpretations

2. 2 x 10mm = 20mm. It would be well to remind students to include the units (here the mm) in their answers since later in the investigation other units will be involved.

3. 5 x 10mm = 50mm.

4. 20 x 10mm = 200mm.

5. 300 x 10mm = 3000mm. This is the same as 3 meters, the height of an ordinary room. Cro-Magnon man was the modern looking ancestor of ours who lived in Europe.

It is important that students not be allowed to become bogged down in math at this point. Perhaps you can display a meter stick to make the relationship more clear.

10mm = 100 years

1000mm (1m) = 10,000 years

Interpretations

6. 10m.

7. 1000m or 1 kilometer

The basis upon which these eras were established will be considered in later investigations. There is no way of knowing how long the Cenozoic Era will continue.

Interpretations

8. 7000m or 7 kilometers.

9. Avoid lengthy consideration of conversion factors relating the English and metric systems. Distances up to a few meters can be demonstrated in the classroom and those of up to a few hundred can be imagined. If your students have already had some practice in thinking in kilometers there will be no need to bring in the mile. If the class is not able to visualize metric distances it would be well to make conversions for them. 7000m is 7km. Multiplying by .6 (the number of miles in a kilometer) it is found that 7km x .6 miles/km = 4.2 miles.

10. 22,500m or 22.5km or 13.5 miles
$225{,}000{,}000 \div 10{,}000{,}000 = 22.5$

11. No comment.

The Paleozoic Era is the first era in which abundant traces of life may be found.

Interpretations

12. 60,000m or 60km or 36 miles.
$600{,}000{,}000 \div 10{,}000{,}000 = 60$

13. If students seem interested you might add that current estimates for the age of the earth stand at about 4.5 billion years, corresponding to a depth in the stack of 450km or 270 miles.

Problems

1. All answers should be considered. Included may be:

a) "We have actual experience with seconds and minutes, but a century is something we have only heard about."

b) "We can practice estimating ten seconds about as many times as we wish in a lifetime. There are fewer minutes to practice on, but still a good many. We cannot "practice" on centuries."

c) "In the first part we dealt with time when we thought about time. In the second part we dealt with time indirectly through the medium of distance."

2. At first students may simply reply "Not very well." The more resourceful student may pursue the idea of constructing a simple timing device such as a water clock or hour glass. Some may also be aware of biological clocks that organisms including man seem to possess. Library research on biological clocks should prove interesting.

FOSSILS--A RECORD OF THE PAST

Soon after death most plants and animals are acted upon by bacteria. The bacteria break apart the remains chemically. This process of being broken apart is sometimes called "decay," "rotting" or "decomposition." It is fortunate that bacteria are present to cause this decomposition. Otherwise, the world would long ago have become quite cluttered with the remains of plants and animals. Eventually all life would have ceased to exist since the materials that compose living things would have been locked up in the carcasses.

When the remains of a once-living thing have been decomposed a new supply of minerals is available. From these raw materials new plants can grow. New generations of animals can grow by using the newly grown plants for food.

Occasionally the process of decomposition fails to act upon a plant or animal which has died. Perhaps the plant or animal dies in a place where the decomposing bacteria are not active. It may be too dry or too cold or in some other way an unsuitable place for the bacteria.

Bone, shell and other hard parts of organisms are unlikely to be attacked by bacteria even under ideal conditions.

Perhaps the bones and other hard parts of the once-living organism are strengthened or replaced by minerals dissolved in water.

If the remains of the plant or animal escape destruction for a long period of time (thousands of years or more) the remains are said to be a fossil.

A fossil does not have to be an actual part of a once-living plant or animal. Any evidence of a plant or animal which lived a long time ago is considered to be a fossil. For example, in certain rocks of the Grand Canyon

of Arizona there are preserved footprints of animals which lived millions of years ago. The animals must have stepped in soft mud along the banks of a river or lake. The mud dried and became "hard as a rock." The footprints are not a part of the animal and never were. Still they are counted as fossils.

Footprints which you may have left in snow or soft ground as you came to school today are not part of you. They never were. However they could serve as evidence of your passing. Your footprints will not be thought of as fossils unless they happen to be preserved for a long time by natural processes.

Figure 7.2. Dinosaur Footprint.

Stony footprints in the Grand Canyon serve as evidence that some sort of animal was once there. Their presence may lead to several interpretations. The interpretation may be an estimate of the size of the animal. It may be a drawing of what the animal looked like, or it may consist of linking the footprints to a fossil skeleton.

It is fortunate that most plants and animals are decomposed soon after death. It is also fortunate that not quite all evidence of former life has been destroyed. There are many interesting things to be learned from the evidence which has been preserved.

Problem

1. It has been said that a fossil is any evidence (preserved for a long time) of the existence of a plant or animal. Which of the things in this list do you think are fossils? Which are not?

Coal
Worm burrow of a million years ago
A gopher hole
Impression (in a rock) of a clam shell
A clam shell found on a beach
Petrified wood
Footprints of a dog in a concrete sidewalk
Amber (tree sap which has turned to stone)

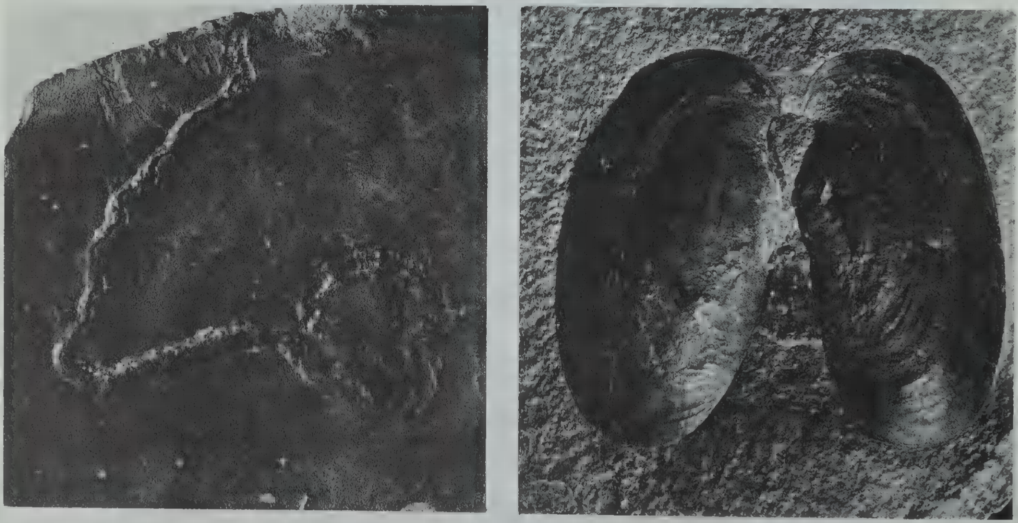


Figure 7.3. Left, Worm Burrow; Right, Clam Shell Impression.

TEACHER MATERIAL

FOSSILS--A RECORD OF THE PAST

This selection can be treated as a reading assignment or as the basis for a class discussion.

The definition of a fossil is not rigid. Its major features are that a fossil must be:

1. Natural. By this it is generally meant that man has not wittingly intervened in the preservation of the material. Since man has been around for only about one-tenth of one percent of the earth's history his intervention is not often a problem. Presumably a bit of charcoal from a cave man's fire could be considered a fossil. But the sketch on the cave wall made by the same man with charcoal from the same fire would not. This, however, is splitting hairs.

2. Evidence of previous life. Sometimes it is not easy to decide whether or not an object is a result of life processes. Certain mineral deposits look just like shells or leaf imprints. Graphite (carbon) deposits in ancient rocks are often assumed to be evidence of life, sometimes because it is difficult to think of any other way for the carbon to have been concentrated. On the other hand, diamonds are pure carbon and they come from deposits in which any former life processes are hard to imagine.

3. Age. Something must be fairly old to be considered a fossil. The preserved remains of a horse of several thousand years ago would be considered a fossil. But the preserved remains of a similar animal which stumbled into the LaBrea tar pits a few years ago would not. However, a few thousand years from now, it would be a fossil.

Fortunately scientists are more likely to debate the meaning and significance of something that has been dug up than argue about whether the term "fossil" can be applied to it.

Problem

1. Coal is considered to be a fossil. It is a natural substance, meets requirements for age, and in certain deposits the impressions of the leaves of plants of which it is made are distinctly visible.

Worm burrow of a million years ago is again a fossil. This item is included to point up the fact that the fossil need not be a part of the animal.

Gopher hole is not considered a fossil. It differs from the worm burrow above by not meeting the criterion of age.

Impression (in a rock) of a clam shell is considered a fossil. The process of turning to rock takes long enough so that the criterion of age is met. Even if the shell itself is missing, its impression constitutes evidence for the existence of the clam.

Clam shell found on a beach does not qualify. Since there has been nothing said to suggest its antiquity it is assumed to be contemporary.

Petrified wood is a common form of fossil.

Footprints of a dog do not meet the criterion of age. Also, the concrete sidewalk suggests the intervention of man.

Amber is a beautiful and interesting fossil in which entire insects are occasionally entrapped. Even without the insects, though, the sap gives evidence of the former existence of trees.

INQUIRY DEMONSTRATION: Interpretation of Preserved Evidence

Students of paleontology are sometimes skeptical of reconstructions made from fossil evidence. Development of such reconstructions depends more upon detective work and sleuthing than on pure guesswork, and students may be made aware of this through attempting some reconstructions of their own. Throughout the reconstruction process, students should be asked to remain aware of which of their statements are observations and the degree of certainty with which each deduction from the observations has been made. They may, thus, become more aware of the amount of deduction which is involved in everyday open-and-shut conclusions they make. And they may also become more appreciative of the processes by which paleontologists, artists, and others working with fossils produce the sketches and descriptions of organisms which lived in the past.

Materials

Fire clay or patching plaster

Paper dishes

Assorted objects

Procedures

A. Prepare a set of imprints similar to those illustrated. If possible, make up at least as many imprints as there will be teams of students. Place an identifying number on each plate with imprint.

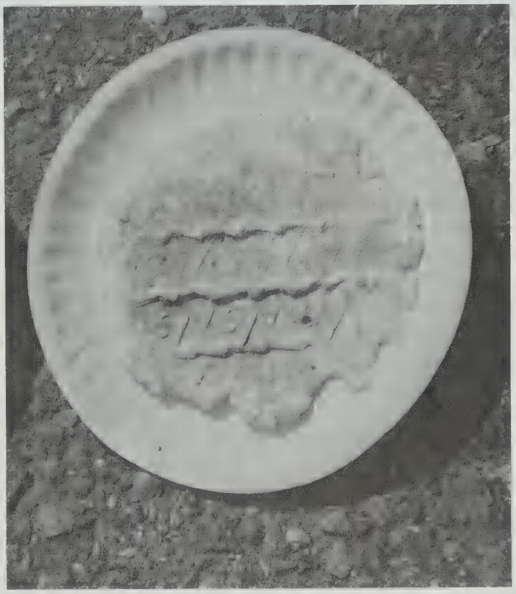
B. Display one of the objects, say a tire print, to the class and invite discussion about it. This will allow the students to recognize the types of observations, interpretations, and conclusions which might be made concerning each of the specimens. (See "Sample Discussion 1." below.)

C. Distribute one imprint to each team. In their notebooks students should write the number of the imprint and notes concerning it for reference in discussion. After a few minutes have the teams exchange imprints. Continue the process until each group has had time to examine and consider each imprint, and then ask for analysis and discussion. (Suggested discussion points for three imprints are outlined below.)

Sample discussion points:

1. A geometric design, probably a tire print. It may have been made by a wheeled vehicle or simply by a tire or tire with wheel being rolled along. In many parts of the world, old tire sections are made into sandals, so the print may have been made by a person walking. The nature of the

"vehicle," (automobile, bicycle, motorcycle, airplane) might be deduced by someone familiar with tread designs. The pattern of wear on the tread might give some indication of the particular vehicle involved, just as a tracker may be able to recognize an animal with a limp. The spacing of the prints, if known, might give insight into the nature of the vehicle (or pedestrian wearing sandals), just as groups of fossil footprints tell more about the size, and gait of the animal involved than does a single print.



Imprint 1.

2. A circle with design within; students may know, from their experience with soft-drink cans, that this imprint could have been made by one of these. They should note that only their <u>experience</u> with real cans allows them to interpret the print. In theory the print could have been made by a disc only a few centimeters thick or by the end of a cylinder many meters long. It is familiarity with soft-drink containers which will suggest to most observers that a can was involved.

The existence of the pull-top, intact, suggests that the container was full, but it is possible that it was opened with a can opener at the other end. Presence or absence of a seam might indicate whether the can was made of aluminum or steel. Since aluminum cans have been introduced relatively recently, the lack of a seam might suggest a date prior to which the imprint could not have been made.

A grocery clerk, familiar with various canned beverages, would be able to tell what brand it might have been or eliminate brands it could not have been. A student lacking such knowledge off-hand might be able to identify the print by comparing it to cans in a market. Paleontologists keep collections of fossils in museums for much the same reason.

Imprint 2.

Imprint 3.

3. A regular pattern, probably the imprint of a bolt. Even though the object itself is not present, students may suggest that it was probably made of metal. The metal might have been bronze or steel, since softer metals--such as lead and copper--are not often used in the manufacture of bolts.

Close inspection of a high quality imprint might show thread wear, cross-threading, stripping or other evidence of use.

Bolts of various designs are commonly used for different purposes. A wood screw is of different shape than a machine screw or a metal screw. Carriage bolts, with square shanks, are often employed for joining wood to metal.

Dimensions of the bolt might tell whether it was of American or European manufacture. The relationships between head and body sizes of bolts have changed periodically. Knowing this and given access to new and old catalogues, a student might be able to date the bolt within, perhaps, twenty years.

The size of the bolt suggests that it was intended to join pieces of material a few centimeters thick and not large girders or thin sheets of metal.

4. A regular, repeated pattern, probably of a twisted rope. A microscopic examination of the cast might give evidence as to whether the rope was of smooth, synthetic fiber, or rougher, natural fiber. The nature of the fiber

Imprint 4.

would give a rough indication of the rope's working strength and possible application. It would also give, in some cases, a clue to the age of the rope. Ropes of natural fiber (hemp and manila) have been used for many years and are still being produced, whereas synthetic ropes were not common more than twenty-five years ago. Paleontologists, working with fossils, are more likely to solve problems in dating in the opposite sense: the appearance of a new type is used as a relative date.

Students may see that collections of imprints, of the same or of various types of items, would supply more evidence for dates than would single, isolated finds.

Knowledge of the locale in which the specimen was collected would be useful. An imprint found near a shoreline might represent a piece of line used to tie up a boat, whereas an imprint from near a deeply rutted mud hole on a back road would suggest a tow rope.

Ropes intended for different uses are made of three and of four laid (twisted) strands, of braided or woven materials, and of continuous fibers enclosed in sheathes.

Knots, if any, in the rope would give further clues as to the use of the rope, and frayed or broken strands would suggest the amount of use experienced by the rope before the imprint was made.

From these and other examples students may, quite correctly, reach the conclusion that there is a great deal of "detective work" involved in interpreting imprints, but that it can be logically and intelligently done. Perhaps the point to be made is that there is a lot of deduction involved in everyday, non-scientific life. The difference between the scientist and the non-scientist is not that one guesses and the other does not. It is more that the scientist is aware of the fact that he is making deductions, whereas the non-scientist may fall into the trap of considering commonly made deductions as facts or observations.

An interesting discussion can sometimes be built around the question, "What things in your daily life do you know as facts with absolutely no guesswork or deduction involved?"

THEN AND NOW

Fossils give some idea of what plants and animals were like many years ago. These plants and animals can be compared to the plants and animals of the present. Think for a moment: what is meant by "compare"? It means to consider ways in which two or more things are similar and ways in which they are different. Here are three possible ways in which different types of fossils compare with animals of the present:

COMPARISON I: Some fossils are found which are unlike any living organisms.

The dinosaurs are a good example of this type of comparison. During Mesozoic time, one or two hundred million years ago, there were huge reptiles on Earth. Nothing like these dinosaurs exists today. Thus dinosaurs are said to be "extinct."

Care must be used in saying that a type of animal is extinct. For over a hundred years, now, people have been looking at fossils in a way that is considered scientific. For many years, one of the animals thought to be extinct was a fish called the "coelacanth" [seal-a-canth]. Fossils of this fish were found in rocks from middle Paleozoic time. Other fossils of coelacanth were found in rocks from later times. However, no coelacanth fossils of ages more recent than late Mesozoic were found. It was supposed that coelacanth had become extinct after the Mesozoic Era. Then, in 1938, a living coelacanth was found! It was brought up from deep in the Indian Ocean off Madagascar. In 1952 a second specimen was caught. Since then several others have been discovered. Thus coelacanths are not extinct; they are simply not common.

There is greater certainty that dinosaurs are extinct. It would not be difficult to imagine that ancient types of fish were hiding in the deep oceans but it is difficult to imagine a place where a forty ton lizard could be lurking undetected.

COMPARISON II: Some fossils from long ago are very similar to present-day animals.

Clams live in sand or mud along ocean beaches and in fresh water. Fossils from the Paleozoic Era show that clams were already common one-half billion years ago.

People like to think of dinosaurs as animals which were very "successful" for a while. Perhaps they were successful. They were certainly spectacular. But the silent little clams were present long before dinosaurs. They are still here seventy million years after the last of the dinosaurs. It is quite likely that clams will continue to live in the sand long after many present day organisms are extinct.

COMPARISON III: The past shows no fossils similar to certain animals of the present time.

Everyone is familiar with birds. It would be difficult to imagine a world without them. Yet rocks from the Paleozoic Era give no indication that there were any birds at that time.

The absence of certain types of fossils does not necessarily mean that such animals did not exist. Maybe the search has not been careful enough. Also, birds have light skeletons which do not fossilize well. They are, moreover, not likely to die in an environment suitable for fossil formation. It is more probable that the skeleton of

a fish will be covered with mud (a good substance for producing and preserving fossils) than that a bird skeleton will. In any era fish fossils are more common than bird fossils.

It is quite certain, however, that birds did not exist before the Mesozoic Era and that they were not common before the Cenozoic Era. Fossils of birds from the Mesozoic suggest that the birds of that time were quite different from present-day birds. There is strong evidence to show that the first birds developed in the early Mesozoic Era. Thus there would have been no birds during the Paleozoic Era.

Problems

1. List characteristics of plants and animals which you think would make them likely to be fossilized.

2. What environments do you think would provide the best conditions for fossilization?

3. Prior to 1938 scientists had thought that coelacanth was extinct. Do you think that the scientists were annoyed or disappointed at being proven wrong?

TEACHER MATERIAL

THEN AND NOW

The purpose of this selection is to suggest that the population of the earth has been changing in quality as well as in number. Examples are given of species which have been persistent over long time intervals, of species which have appeared in relatively recent times, and of those which have become extinct. Students may be able to think of other examples of each category.

Problems

1. Plants and animals are more likely to leave fossils if they are:

    abundant
    live in certain habitats (see Problem 2)
    have hard parts such as shells or bones

2. Organisms are more likely to leave fossils if they live:

    in water rather than on land or in the air
    in mud, as does the clam
    in calm water, which will not break up the remains before fossilization can occur

The factors mentioned in regards to Problems 1 and 2 bring up the idea of "bias."

Ideally, a collection of all the fossils from a given time era would give a pretty good idea of the types and numbers of organisms which were living during that era. But some organisms are not as likely to be preserved as others. Reasons include the nature of the organism and

the habitat. Thus a complete collection of fossils does not represent the actual population of an era.

The clam, for example, is an organism which is ideally suited for preservation. It has a hard shell and it lives in an area of deposition. The earthworm is not as well suited for preservation. Its habitat, soil, may be subjected to all manner of disrupting forces after demise of the organism. And the animal itself has nothing in the way of bones or a shell which would fossilize easily.

Collectors have little control over the bias that exists in their samples of past life. The numbers and types of organisms fossilized are completely beyond control. Man may have some slight control in choosing the areas in which fossils are sought.

The best approach, really, is to recognize that bias exists and attempt to allow for it.

3. In theory, at least, a scientist is always pleased to learn something new. It is somewhat more difficult to be genuinely delighted when one's pet theory has just been overwhelmed by proponents of a different view. In the case of the coelacanth there had been little debate as to the existence of the animal. Everyone assumed it was extinct, so no one had been forced out onto the limb of proclaiming its non-existence. Most scientists were probably quite pleased at announcement of the find.

A TIME SCALE FOR THE EARTH

Centuries, decades, years, days, minutes, and seconds are all commonly used units of time. Each has a particular use in everyday descriptions of time. For convenience, the long history of the earth has been divided into units of time. The largest unit is called an <u>era</u>, of which there

Figure 7.4. GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	DATES (years ago) of time division		CHARACTERISTIC
			BEGAN	ENDED	LIFE
CENOZOIC	Quaternary	Recent	12,000 ?	?	
		Pleistocene	600,000	12,000 ?	
	Tertiary	Pliocene	11,000,000	600,000	
		Miocene	25,000,000	11,000,000	
		Oligocene	40,000,000	25,000,000	
		Eocene	60,000,000	40,000,000	
		Paleocene	70,000,000	60,000,000	
MESOZOIC	Cretaceous		135,000,000	70,000,000	
	Jurassic		180,000,000	135,000,000	
	Triassic		225,000,000	180,000,000	
PALEOZOIC	Permian		270,000,000	225,000,000	
	Pennsylvanian		330,000,000	270,000,000	
	Mississippian		350,000,000	330,000,000	
	Devonian		400,000,000	350,000,000	
	Silurian		440,000,000	400,000,000	
	Ordovician		500,000,000	440,000,000	
	Cambrian		600,000,000	500,000,000	
PRECAMBRIAN			4,500,000,000 ?	600,000,000	

are four. We are living in the Cenozoic (recent life) Era. Other eras are the Mesozoic (middle life), Paleozoic (ancient life), and Precambrian (before the Cambrian, the earliest part of the Paleozoic). Each era has been subdivided into shorter units called periods. The periods of the Cenozoic have been divided into still smaller units termed epochs. In Figure 7.4 you can find the various units of time and the approximate dates of each unit.

INVESTIGATION 7.2: Fossils on the Time Scale

Materials

No special materials needed

Procedures

A. Copy the chart in Figure 7.5 in your notebook.

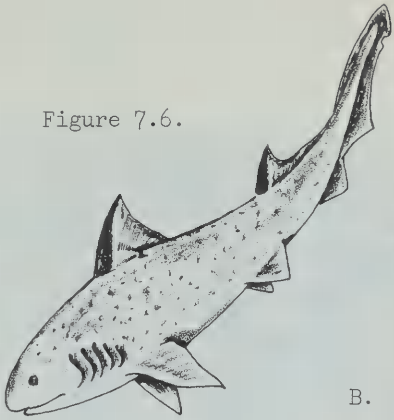
Figure 7.5.

TYPE OF ORGANISM	AGE OF FOSSIL		LENGTH OF EXISTENCE	COMMENTS: Habitat, food, etc.
	Oldest	Most Recent		
A	180,000,000 years	Modern	180,000,000 years	Ocean, meat eater
B				
C				
D				
E				
F				
G				
H				

B. Study the following pages of reconstructions of eight plants and animals that have been found as fossils. The reconstructions show what the organisms may have looked like based on the fossils (bones, shells, imprints, etc.) available. Below the name of each organism is found first--the geologic time unit in which the oldest known fossil has been found, second--the most recent unit in which evidence of the organism has been found. Additional information is also given for some of the reconstructions.

C. Refer to Figure 7.4, A Geologic Time Scale, and determine when the oldest known fossil first indicates the existence of the organism. Write the number of years in the column titled "oldest." Put the age of the most recent fossil in the appropriate column. Subtracting these ages will give you the number of years that the type of organism lived on Earth. The column titled "comments" can be used to list any information about the organism you may think is important. A habitat is a place in which an organism lives; such as land, sea, trees, burrows, etc. By looking at the organism's shape, its teeth, its legs, or its fins, you may be able to decide where it lived or what it ate. To help you get started the information on organism A has been provided for you.

Figure 7.6.



B. Lingula, Late Ordovician - Recent.
Body covered by two valves (shells).

A. Shark,
Jurassic - Recent.

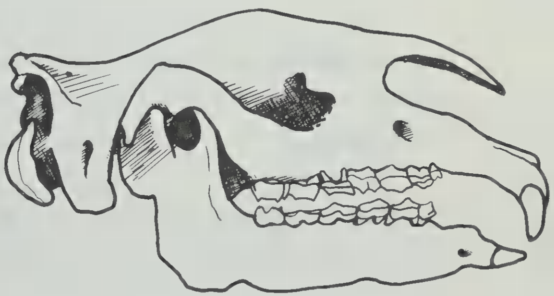
C. Sigillaria, Pennsylvanian - Permian.
Tree-fern reaching heights of 40 feet.

D. Acer, Eocene - Recent.
Maple tree leaf; a flowering plant.

E. Diplodocus, Jurassic - Cretaceous. Body lengths up to 26m; skull, above, about .6m long; a reptile.

F. Tyrannosaurus,
Cretaceous - Late Cretaceous.
Body lengths up to 14m;
skull about 1.2m long;
a reptile.

G. Didelphis, Late Cretaceous - Recent. Commonly known as an opossum; a mammal.



H. Baluchitherium, Oligocene - Mid-Miocene; Hornless rhinoceros; 5.5m high at the shoulder; a mammal.

Interpretations

1. What kinds of foods do you think
   a) Diplodocus ate?
   b) Tyrannosaurus ate?
   Give reasons for your answer.

2. Do you think either could have eaten maple leaves as part of its diet? Give reasons for your answer.

3. It is thought that coal was formed from the remains of ferns and other soft bodied plants of late Paleozoic. What does this suggest about the ancient climate of the regions of the United States where coal is found?

4. Write a short paragraph describing the value of the statement, "No animals lived on land before late Devonian times because the oldest amphibian fossil is of that time."

5. Comparing Triassic with Recent times, in which environment, land or sea, have the organisms changed the most? Why do you think this is so?

6. Now that you have completed the chart, you can add some information to the Geologic Time Scale (Figure 7.4). In the column headed: Characteristic Life, add the names of the eight plants and animals you have just considered. Also add the organisms discussed earlier in this section. When a plant or animal is mentioned later in the book, add its name to the list in the appropriate place.

TEACHER MATERIAL

INVESTIGATION 7.2: Fossils on the Time Scale

In this investigation students should become familiar with the Geologic Time Scale and begin to have a "feel" for the great changes in plants and animals that have taken place on Earth. It should be emphasized that the fossils presented represent only a very scant sample of the thousands of fossils now known.

Procedures

A. You may want to give students a dittoed copy of Figure 7.4 to save time in copying the chart.

B. No comment.

C. The completed chart may look like the following.

Figure T-7.1.

TYPE OF ORGANISM	AGE OF FOSSIL		LENGTH OF EXISTENCE	COMMENTS: Habitat, food, etc.
	Oldest	Most Recent		
A	180,000,000	Modern	180,000,000	Ocean dweller, meat eater, fast swimmer
B	500,000,000	Modern	500,000,000	Lives in water (ocean), eats small floating food
C	330,000,000	225,000,000	105,000,000	Land plant, probably warm humid climate, probably a "soft wood"
D	60,000,000	Modern	60,000,000	Land plant, a "hard" wood
E	180,000,000	70,000,000	110,000,000	Land or swampy area, judging from teeth a plant eater
F	135,000,000	70,000,000	65,000,000	Land, a meat eater
G	70,000,000	Modern	70,000,000	Land, a meat eater
H	40,000,000	18,000,000	22,000,000	Land, a plant eater

Interpretations

1. Judging from its flat-crowned teeth and small head, *Diplodocus* ate plants. *Tyrannosaurus*' sharp teeth and large mouth indicate a meat eater.

2. *Diplodocus* is the only consideration here. Since *Diplodocus* became extinct before Acer appeared it is unlikely that *Diplodocus* ate maple leaves.

3. The coal mining regions were probably warm, swampy areas during late Paleozoic times.

4. Student answers will depend in part on their awareness of the "primitive" nature of Amphibians. Points to be considered are:

a) The fossil record is incomplete and older land tetrapods may be found.

b) Invertebrates (worms for example) may have been on land prior to this but they do not leave good fossils.

c) Life probably had its origin in the sea.

5. Land organisms have exhibited the most dramatic changes. Students may or may not have any reasons in mind that would explain this observation. Do not press for reasons at this time. Later investigations will suggest that the more changeable land environment results in the more rapidly changing inhabitants.

6. The Characteristic Life column should be completed as in Figure T-7.2. Perhaps you could have the Geologic Time Scale (Figure 7.4) reproduced and given to the students. They could then fill in the column headed: Characteristic Life.

Figure T-7.2. GEOLOGIC TIME SCALE

A	PERIOD	EPOCH	DATES (years ago) of time division		CHARACTERISTIC
			BEGAN	ENDED	LIFE
	Quaternary	Recent	12,000 ?	?	
		Pleistocene	600,000	12,000	
	Tertiary	Pliocene	11,000,000	600,000	Man
		Miocene	25,000,000	11,000,000	
		Oligocene	40,000,000	25,000,000	Baluchitherium
		Eocene	60,000,000	40,000,000	
		Paleocene	70,000,000	60,000,000	Acer
	Cretaceous		135,000,000	70,000,000	Tyrannosaurus
					Didelphis
	Jurassic		180,000,000	135,000,000	Heterodontus
					Diplodocus
	Triassic		225,000,000	180,000,000	Birds
	Permian		270,000,000	225,000,000	
	Pennsylvanian		330,000,000	270,000,000	Sigillaria
	Mississippian		350,000,000	330,000,000	
	Devonian		400,000,000	350,000,000	Coelacanth
	Silurian		440,000,000	400,000,000	
	Ordovician		500,000,000	440,000,000	Lingula, Clams
	Cambrian		600,000,000	500,000,000	
			4,500,000,000	600,000,000	

CHANGING LIFE FORMS

There is much evidence to suggest that life forms change. Dinosaurs and dodo birds are now extinct. Men and horses and dogs live on a planet which in times past had no airedales, appaloosas, or people. How do such changes occur?

Charles Darwin, a scientist of the last century, described the process by which he thought these changes could occur. He also gave many examples and much evidence to support the model he described. In the past one hundred years more evidence, not available to Darwin, has been discovered. This more recent evidence fills in many details of the way in which the process operates. The current way of thinking about evolution (the changing of types of life forms on Earth) is in agreement with many observations. Therefore it is considered to be a good model. Other ways of thinking about evolution have not proved as useful.

Four main ideas comprise the model. The first idea is that most types of life, whether they are plants or animals, reproduce at a higher rate than seems necessary. For example, if the total number of cats on the earth is not going to change it seems that each pair of cats should produce two kittens to take its place when the older pair dies. An apple tree should produce one seedling before it dies.

The observed fact is that this does not happen. If you have experience with cats you know that litters contain numerous kittens. In her lifetime one female cat can produce enough young to keep your family, your neighbors and all your friends well supplied with cats. Unless something is done the cat population rises.

Each apple contains several seeds capable of growing into new trees. Each season an apple tree produces a number of apples. And one tree can continue to bear for quite a few years. You may wonder why the entire earth is not forested with apple trees (with a cat on each branch).

These are examples of what is meant by high rates of reproduction. Among "lower" forms of life the overproduction is even greater. One pair of houseflies can produce a fantastic number of young. One fern plant produces an incredible number of reproductive spores.

The second thing to note, if you are to understand evolution, is that there are differences among the offspring of one set of parents. Like their parents, all kittens are cats. There are no sharks or parrots in the litter. But within the limits of what are still thought of as cats there are many variations. Not all the kittens in one litter are of the same color and markings. Some will be larger than others. Some may be friendlier. There are doubtlessly internal differences which are not easily observed.

Similarly, not all seedlings produced by the seeds from one tree are identical. Some will grow faster than others. Some may bear more fruit than the rest.

Third, try to imagine what would happen if man were not present to have an effect on the survival of kittens, apple trees and the like. No one would feed the cats. They would eat only what they themselves could catch. Trees would not be sprayed, pruned or irrigated.

Only those cats, apple trees and other living things which could survive the tests of nature would live. By "tests of nature" are meant such things as heat, cold, shortages of food and living space, and competition.

Finally, a dead cat or a dead apple tree or anything else which has not survived is not going to reproduce. Only those plants and animals which survive to maturity can produce offspring. The offspring will resemble their parents and perhaps have some of the characteristics which allowed their parents to survive. This process has been referred to as "survival of the fittest."

The ways in which different characteristics are passed on from parents to their offspring are well known. The science which describes this process is known as "genetics." However, at the present time you should concentrate on the broader view of evolution, not the details of how one part of the process operates. To summarize:

1. Each type of plant and animal produces more offspring than usually survive.
2. There are slight differences among the individuals of any type.
3. The members of each type face tests. Because of the slight differences among individuals some are more likely to survive than others.
4. Only the survivors can reproduce. Individuals which lacked some necessary quality will die off.

As a result of the four steps listed above happening time and again a type of plant or animal may gradually change. This gradual change is known as evolution.

Problem

Try to calculate the total number of offspring which could be produced by a member of some type. To do this for an apple tree you would count the number of seeds in one apple. Multiply this by the number of apples you think a tree could produce in one year. Multiply this by the number of producing years in the life of an apple tree.

You could make a similar calculation for cats, flies or any other organism for which information is available.

TEACHER
MATERIAL

CHANGING LIFE FORMS

In the student text the word "type" is used to avoid introducing the term "species" in order to minimize vocabulary.

Problem

Depending upon assumptions made by the students, the total potential number of seedlings for a single apple tree should range between 5,000 and 1,000,000. In any case, it is apparent that the potential greatly exceeds the required one replacement. Some possible responses are shown in the table, Figure T-7.3.

Figure T-7.3.

	Number of Seeds	Apples/Tree	Years/Tree	Total
Minimum Reasonable Assumption	5	100	10	5,000
Maximum Reasonable Assumption	10	1,000	100	1,000,000

ADDITIONAL ACTIVITY (Optional)

The purpose of this activity is to have students recognize that the genetic potential for evolutionary change is present in each species at all times. This is accomplished by recognizing that there are differences between individual members of any one species.

Materials

Two dozen or so representatives of any single species.

Comment

The species can, of course, be human. If you have a plentiful supply of clam or oyster fossils, or of snail shells, or simply recollections of what dogs and cats look like, these can be used.

Procedures

Student should list all variations between members of the same species.

Interpretations

1. For each variation students should attempt to tell whether the variation is due to genetic (inborn) or other factors. For example a taller dog may be taller because its genes have given it directions to be tall. On the other hand it may be older than a smaller dog, or the taller animal may have enjoyed a better and more plentiful diet than the shorter one. (Such distinctions are not easy to make, and opinions will vary.)

2. For each type of difference noticed, size, shape, etc. students should attempt to name two situations, one of which would favor survival of each of the differing members. For example, if it is noted that some animals are taller than others it might be suggested that a) taller animals are better suited for defense against aggressive enemies, and b) that shorter individuals are more likely to be able to find hiding places if such are needed.

INQUIRY DEMONSTRATION: Reproductive Capacity of _Drosophila_

The tremendous reproductive capacity of the common fruit fly, _Drosophila_ can be shown with locally trapped specimens.

Materials

Large wide-mouth jar (peanut butter or pickle)
Gauze
Tape
Ether (optional)
Drosophila food
Yeast
Lens, 1"

Procedures

A. To trap wild flies place an open jar in a shaded area with a piece of banana, peach, or a few grapes in the bottom of the container. In warm weather, several flies should be found on the fruit in just a few hours.

B. Cover the jar and remove to the laboratory.

C. The captured flies may be etherized by placing a wad of cotton soaked in ether into the capture jar and closing with a lid. As soon as the flies cease their activity remove the cotton. _Do not over-etherize_. Caution: Ether is highly flammable. All ether containers should be disposed of at the end of the school year to prevent decomposition and possible formation of explosive products.

D. Remove the flies with a small paint brush or cotton tipped swab stick. Select two males and two females using Figure T-7.4 to distinguish sexes. The one-inch lens may be useful in this process. Place the flies into another large jar with Drosophila medium.

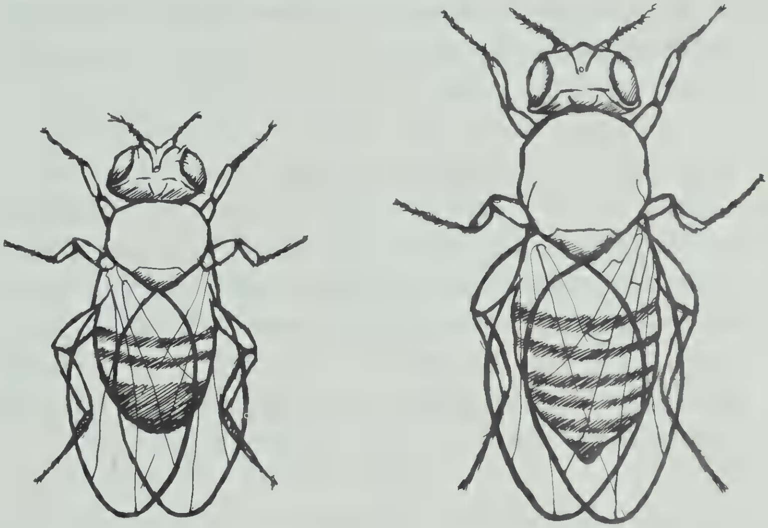


Figure T-7.4. <u>Drosophila melanogaster</u>, left, Male; right, Female.

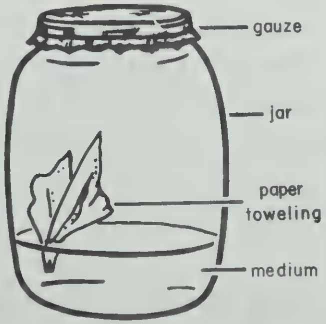


Figure T-7.5. <u>Drosophila</u> Culture Jar.

E. Food for the flies can be obtained under the name Instant Drosophila Medium listed in the Carolina Biological Supply Company catalog. Drosophila medium may be prepared locally by adding 5g powdered agar to 75ml cold water and heated with stirring until dissolved. Add one mashed ripe banana to the solution, heat and continue stirring until smooth. Remove from heat and add one ml propionic acid or Tegospot M solution as a mold inhibitor. Pour liquid into jar and allow to cool.

F. Just prior to introducing the flies you should push a 2" x 5" strip of white paper toweling down into the medium. This acts as a pupation site for the larvae. In addition add a few grains of dry bakers' yeast to the surface of the medium. The larvae eat the fungus (yeast), not the medium. Cover the mouth of the jar with a square of gauze and tape in place. See Figure T-7.5.

G. You may wish to omit Procedures C through F due to lack of supplies. In this case you can use the collecting jar as a permanent container for the flies by mashing a ripe banana in the bottom of the jar, seeding with yeast, and adding more toweling to absorb the liquid that will form. Mold will usually form in such a set up as the banana decomposes into a syrupy liquid. Most flies will become caught in the liquid but this may show one reason flies do not "cover the earth."

H. Adult Drosophila develop from eggs in about ten days at 25°C. Higher temperatures increase mortality and lower temperatures slow development.

Suggestions for use of *Drosophila* culture.

To perform the demonstration in winter you will have to maintain a culture of flies from fall when the wild flies are most abundant. Also, you may be able to obtain a supply of *Drosophila* from a local high school or college that is conducting genetics experiments.

You may introduce the demonstration by telling students how you collected the flies (if you did) and how they are being reared. Invite students to examine the new culture and count the flies in it. Ask for predictions about the future of the culture, especially how many offspring may be produced and in what length of time. Record these predictions and set the culture aside for about two weeks.

A discussion of the results should bring out the idea that the flies produce a tremendous number of offspring and that most offspring do not survive.

A worthwhile project for interested students would be testing the effects of different temperatures on the reproductive capacity of the flies.

CATS

Cats may serve as a good example of the way in which life forms evolve. During Mesozoic time there were no cats. Today there are many types of cats, from the large jungle cats to smaller types kept as pets. Just what is a cat? Where did cats come from?

Cats are "carnivores," or meat eaters. They have long fangs for stabbing their prey and other teeth which are useful in chopping meat into chunks of a size which can be swallowed. They have no molars, or grinding teeth, such as those found on grazing animals. Cats are capable of very rapid motion for short periods of time. They are fairly smart and have efficient noses and eyes. They have claws which can be extended for use (in tree-climbing or fighting) and retracted when not in use.

You could probably say a lot more about particular cats you have known or read about. But this brief description will give you a few things to consider.

Among the fossils found from early in Cenozoic time are those of animals called "Creodonts." Although they did not have the fangs of present-day cats, the Creodonts are thought to have been carnivores. In fact the name Creodont means "flesh (eating) teeth."

Creodonts had very little space in their skulls for brains. The interpretation is that they were rather stupid animals. Creodonts were small in size with long bodies and clawed feet. Such an animal would probably be good at climbing trees. Perhaps they climbed trees to avoid being attacked by other carnivores.

All in all, Creodonts were not very impressive as carnivores. It is hard to think of a present-day animal which would be slow enough and stupid enough to get caught and eaten by a Creodont. Perhaps the grazing animals of the early Cenozoic were not as alert and fast as present-day deer and horses.

Fossil records of grazing animals show a steady increase in size and ability to run in the early Cenozoic. Most Creodonts probably starved to death. There are none living today.

The descendants of one group of Creodonts did survive, though. Perhaps they survived in this way.

Imagine a litter of six young Creodonts. (It is reasonable to imagine a seemingly larger-than-necessary litter because that is the way things happen today.) Four of these young animals are, like most Creodonts, pretty slow. One is even slower. One is a bit faster. (This is a reasonable assumption since in animals of today there are slight differences found, even among those from the same litter.) There is not always enough food for all six Creodonts. (This is the kind of thing mentioned earlier as a "test of nature.") The particularly slow Creodont starves. The others survive, find mates and produce offspring. The offspring have a tendency to resemble their parents. Since the parents, in this case, are all of average or better-than-average speed it is possible that all will be fast enough to be capable hunters.

Figure 7.7. Creodont.

As you may know, traits can "skip" a generation. Perhaps the trait of slowness skips one or two generations and then shows up again. When it does the slower individuals are more likely to starve.

After a few generations in which the slower animals are eliminated as they appear, only those animals which would be called "average" or slightly faster are left.

But now the average speed is slightly faster than it was. The surviving Creodonts are just slightly faster than their ancestors of a few generations back. It may seem that it would take a long time to eliminate the slower Creodonts. Assuming that a generation for Creodonts was five years (not unreasonable considering carnivores of today), in ten million years there would be $10{,}000{,}000 \div 5 = 2{,}000{,}000$ generations of Creodonts. This could well allow for noticeable changes in speed.

CALCULATING RATES OF CHANGE

Many people believe that if man is not careful he may destroy much of the life on Earth including himself. There are a number of ways in which this might be done. One way involves changing the surroundings in which we live. Man now has the capability of causing small but important changes in the atmosphere. He has proven that he can completely change the types of plants and animals living in certain areas. Perhaps he may in some way change his surroundings so that humans can no longer live on Earth.

Or is there any danger? Evolution, the gradual change in a type of organism as time goes by and conditions change, can be observed. Man himself has evolved from other types of life. If he now causes some change in conditions on the planet he lives on will he not simply evolve to fit the new conditions?

In order to help answer this question you will now consider the rate at which evolution has proceeded in two kinds of organisms.

The small dinosaur, Euparkeria, lived early in the Triassic Period. This dinosaur was about one meter long. It may well have been an ancestor of Diplodocus, another dinosaur. Diplodocus lived in late Jurassic time. A Diplodocus skeleton over 26 meters long has been found.

Problems

1. In years, how long ago did Diplodocus dinosaurs exist? (If necessary, refer to Figure 7.4.)

2. In years, how long ago did Euparkeria live?

3. How many years were there between the time of Euparkeria and the time of Diplodocus?

It is difficult to estimate the length of a generation for dinosaurs. Twenty years may not be too far off. A generation for Euparkeria might have been less than this. For a large dinosaur such as Diplodocus a generation could have been longer.

Problems

4. How many generations of dinosaurs were there between the time of Euparkeria and the time of Diplodocus?

5. What is the difference in length between Euparkeria and Diplodocus?

6. Find the average increase in length per generation by dividing your answer to Problem 5 by the answer to Problem 4.

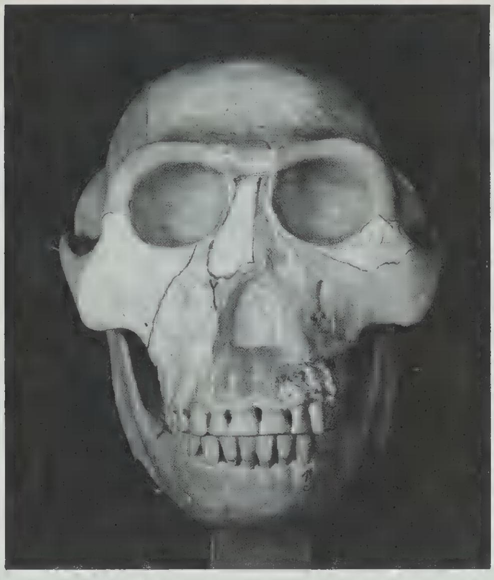
The three figures show skulls of modern man and two types of individuals thought to be the ancestors of modern man. Below each figure is the name given to the type of individual, the age in years of fossil evidence of its existence, and the average brain size in cubic centimeters.

Problems

7. Assuming that a generation is twenty years in these individuals, what has been the average increase in brain size per generation?

8. Would the increase per generation be greater or smaller if the time for a generation was only 15 years?

Figure 7.8.



A. Australopithecus,
2,000,000 years ago.
Brain 700cc.

B. Homo erectus,
700,000 years ago.
Brain 1000cc.

C. Homo sapiens, Modern. Brain 1500cc.

TEACHER MATERIAL

CALCULATING RATES OF CHANGE

Diplodocus with his 26m length (87 feet) was the longest of the dinosaurs. At 25 tons, however, he was not the most massive, that honor falling to his cousin Brachiosaurus which weighed more than 50 tons. Both were vegetarians.

Problems

1. The Jurassic ended as the Cretaceous began, about 135 million years ago.

2. Early Triassic occurred about 225 million years ago.

3. 225,000,000 - 135,000,000 = 90,000,000 years.

Generally the time till maturation and life-span are greater for larger animals.

Problems

4. 90,000,000 ÷ 20 = 4,500,000 generations.

5. 26m - 1m = 25m

6. 25m x 1000mm/m = 25,000mm
   25,000mm ÷ 4,500,000 = .0055mm/generation

7. Using the same technique as used for Problems 1 - 6:
Time = 2,000,000 years
2,000,000 years ÷ 20 yrs/generation = 100,000 generations
Increase in brain size = 800cc
Increase per generation 800cc ÷ 100,000 generations = .008cc/generation

It should be noted that brain size, or body length probably has not increased in a linear fashion as may be indicated by these calculations. Changes probably took place in "spurts" between static periods. The point is that modern life is derived from ancient forms through an accumulation of small changes over a very long time.

Problems

8. Increase per generation would be smaller if there were a shorter generation time and, thus, more generations.

ANCIENT CLIMATES

Those who study life of the past are not satisfied with knowing the appearances of ancient plants and animals. They would like to know all they can about the conditions in which the organisms lived. You will be asked to make some interpretations about the climates of various times and places based on evidence of fossils.

Mammals (horses, dogs, cats, man, etc.) are animals that have the ability to maintain a constant body temperature while living in an environment of changing temperature. In both summer and winter your body temperature is very near 37°C (98.6°F). Reptiles (snakes, lizards, alligators, turtles, etc.) are animals that do not have constant body temperatures. Instead, their bodies assume the temperature of their surroundings. When the body temperatures of mammals and reptiles fall to low extremes or rise to high levels their body functions are affected, and they may die.

Problems

1. Which kind of animal, mammal or reptile, would you expect to find living in both cold and warm climates?

2. Which kind of animal would be limited to a certain climate?

Plants (and animals) usually reproduce as the result of the union of male (sperm) and female (egg) reproductive cells. In mosses and ferns the sperm swims to the egg through a thin layer of water covering the plants. In flowering plants (trees, grasses, shrubs, etc.) the sperm is carried in wind- or insect-borne pollen grains.

Problems

3. Which type of plant, mosses and ferns or flowering plants, would you expect to find in both dry and moist climates?

4. Which would be limited to a certain climate?

Copy Figure 7.9 in your notebook. It lists five areas and the fossils that have been found in each. Describe what you think the ancient climate was like for each area at the time when the plants and animals lived there.

Problems

5. Record your answer under "Probable Climate."

Figure 7.9.

AREA	FOSSILS	PROBABLE CLIMATE
A	mosses, ferns mammals	
B	reptiles flowering plants	
C	small reptiles no plant fossils	
D	mammals flowering plants	
E	mosses and ferns reptiles	

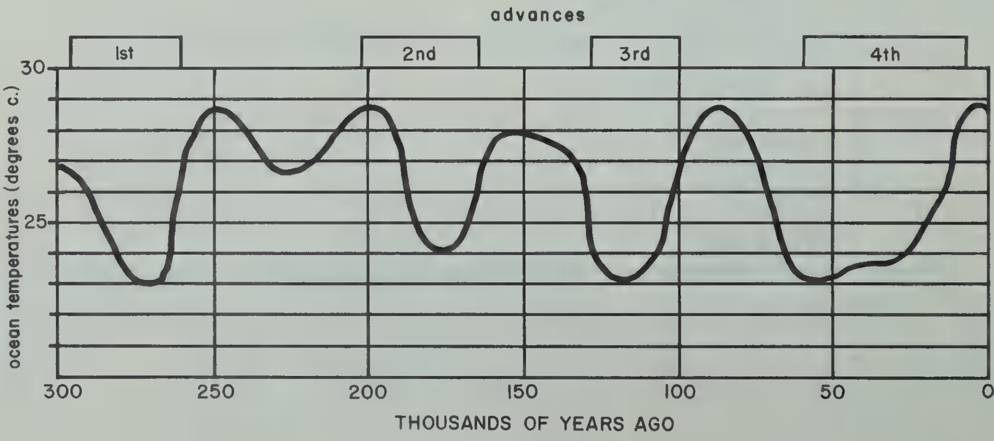
6. More recent fossils from area A include alligator remains in addition to the mammal, moss, and fern fossils. What does this information tell you about the more recent climate of area A?

7. Does the presence of alligator fossils in only more recent times allow you to conclude that the climate of area A changed? Give reasons for your answer.

Fossils are used as indicators of rather broad ranges of climate for particular regions of the earth. They can also be used to compare climates of two or more areas. Only recently a way has been devised to obtain accurate information about past temperatures of the oceans. By careful analysis of the chemical oxygen in fossils of ocean dwelling animals it is now possible to determine the temperature of the water the animals lived in.

This knowledge of past ocean temperatures has given new information about the "ice ages." During the ice ages, huge glaciers covered the northern parts of the United States and Europe. On four occasions glaciers advanced

Figure 7.10. Ocean Temperatures and Glacial Advances.



from the north to cover areas where Chicago, Berlin and Moscow now stand. According to some studies the first glacier formed about 300,000 years ago. It melted after about 40,000 years. Then, about 200,000 years ago the glaciers advanced for a second time. Figure 7.10 shows the dates of the four periods of glaciation with the corresponding ocean temperatures.

Problems

8. What is the largest ocean temperature change associated with the occurrence of a glacial advance?

9. Assuming we are now in a warm period, how much of a drop in average ocean temperature would probably be associated with a fifth glacial advance?

For Discussion

1. Review "Calculating Rates of Change." Imagine a "sudden" change in conditions on Earth such as an ice age. "Sudden" here refers to, perhaps, 100 years. Do you think man could survive such a change?

TEACHER MATERIAL

ANCIENT CLIMATES

It is important that students understand the difference in temperature regulation between mammals and reptiles.

Problems

1. Since mammals are temperature "independent" within certain extremes you should expect to find them in areas of warm and cold. Other criteria such as food and water are not considered here. Fossil mammals as a class are not good indicators of temperature. Some mammal species may appear to be good indicators (monkeys--warm, polar bears--cold) but few such <u>fossil</u> types exist.

2. Since reptiles are most efficient in warm temperatures you would expect to find them in warm climates only. Thus reptiles may be considered "narrow range indicators" of warm temperatures.

3. Flowering plants are found in both climates and as such are not good indicators (as a group) of moisture conditions.

4. Mosses and ferns are found in moist climates both warm and cool. They are not found in dry climates because the sperm needs a fluid in which to swim to the egg.

5. Below (Figure T-7.6) is a completed chart. The interpretations may be the basis for a class discussion, especially interpretations given to the absence of a fossil type.

Figure T-7.6.

AREA	FOSSILS	PROBABLE CLIMATE
A	mosses, ferns mammals	moist; no reptiles may indicate cool but not conclusive
B	reptiles flowering plants	moist or dry; no mosses may indicate dry but not conclusive; warm
C	small reptiles no plant fossils	no plants may indicate arid not conclusive; warm
D	mammals flowering plants	unknown; may be cool and dry but not conclusive
E	mosses and ferns, reptiles	moist and warm

6. Since alligators are reptiles, their presence indicates the climate was warm.

7. There is not enough information to conclude that the climate changed. In order to decide whether a change had occurred it would be necessary to know the earlier climate of area A. The earlier fossil assemblage does not provide such information.

It has been found that temperature affects the rate at which isotopes of oxygen are accumulated in carbonates of limestone, coral and skeletons of aquatic animals. In ocean water calcium carbonate formed at $0^{\circ}C$ will have a 1.026:500 ratio of oxygen 18 to oxygen 16. At $25^{\circ}C$ the ratio will only be 1.022:500. Careful analysis of isotopic ratios in marine fossils now provides a method for determining actual paleotemperatures.

Problems

8. A temperature fall of 6°C between the third and fourth glaciations is the largest.

9. It has been suggested that a temperature drop of 4-6°C could bring on another ice age.

For Discussion

1. Students may be asked to find background information about the problem before a class discussion. Much speculation about the occurrence of another ice age is in current literature.

Physiologically, man could probably survive such a fate. Man's ability to influence the immediate environment (clothes, housing, etc.) and his ease of migration seem to make little of the event. But the fate of the organisms that we depend upon for food might be a different matter.

The vast corn and wheat belts of the world could not continue to feed our large population (much of which is starving now) or our domesticated animals. The adaptation of domesticated plants and animals to different soils and climates would be in doubt since we have very carefully discarded variations not suitable to their present environment.

AIR CONTAMINATION AND TEMPERATURE

Man does many things that may influence the temperature of the earth. One of his more significant activities has been introducing a large amount of small particles of solids (such as smoke) and tiny droplets of liquid into the atmosphere. There are many examples of places where the amounts of these particles are ten times greater than they were five years ago.

This type of air pollution has two main effects: It reflects energy from the sun and thereby reduces the amount reaching the earth. It can also cause clouds to form. (In a later investigation you will see the relationship between particles in the air and the formation of clouds.)

The clouds will decrease the amount of energy which reaches the earth from the sun and can also change the patterns of rainfall. Depending upon the temperature and the amount of moisture in the air, the amount of rainfall may increase or decrease.

From 1951 to 1965 LaPorte, Indiana, which is 30 miles downwind from large steel works, had 31% more rain, 38% more thunderstorms and 245% more days with hail than nearby communities.

On the other hand, during cane harvest season in Queensland, Australia, when the leaves are burned, large amounts of fine smoke particles are introduced into the atmosphere. Areas downwind from these fires have experienced a decrease of up to 25% in the amount of rainfall, while neighboring areas not in the path of the smoke have received the normal amount of rain.

Most people have seen the vapor trails from high-flying aircraft. It has been estimated that the high altitude cloud cover between Europe and North America has been increased from 5 to 10% as a result of these condensation trails. It is within the realm of possibility that

increased air traffic could result in 100% high altitude cloud cover along the air routes. While we can expect rain to remove the things we put into the air at a low altitude relatively rapidly, the high altitude materials remain in location for a longer time and may produce long term effects.

Clouds are very effective in reducing the amount of energy that reaches the earth from the sun. At present the worldwide average cloud cover is about 31% of the earth's surface. It has been estimated that an average cloud cover of 36% could reduce surface temperatures enough to mark the beginning of a new ice age.

We really don't know very much about our ability to change the environment, and it seems that the relationship between weather and air pollution should be studied more thoroughly. It also seems unwise to wait for the answers before trying to reduce the amount of pollution introduced into the atmosphere.

[illegible]
cloud [illegible] along the air route. While we [illegible]
rain to [illegible]
altitude [illegible]
[illegible]
effects [illegible]
cloud [illegible]
[illegible]
the worldwide average cloud cover is about [illegible]
earth's surface. [illegible]
cloud cover [illegible]
[illegible]
[illegible]
[illegible]
between [illegible]
thoroughly [illegible]
before flying [illegible] the amount [illegible]
into the [illegible]

[illegible]

[illegible] the leaves are injured. Larger [illegible]
[illegible] are introduced into the [illegible]
[illegible] these trees have [illegible]
[illegible] amount of rainfall [illegible]
[illegible] of the smoke have [illegible]

Section Eight:

The Changing Atmosphere

PREVIEW

In Section Eight students will measure, record, analyze and--possibly--predict changes that occur in the atmosphere. Throughout the section students should be encouraged to make and record various measurements and observations of atmospheric conditions at home and after school. Upon completion of the section students should be able to correlate these data with weather changes as they occur in your area.

Initial measurements are made of air temperatures (Investigation 8.1) and are intended to establish the pattern of observation and recording of data. The origin of convection currents; effect of radiation on land and water temperatures; measurement of barometric pressure, and wind direction and speed follow as the dynamics of heated air are considered.

Students move from investigations of changes in water's form under various conditions to the topic of cloud formation and types. Simple devices may be constructed to measure dew point, relative humidity, and rainfall.

As each weather factor is considered, its periodic measurement and recording should be initiated. You may want

to encourage students to record measurements and predictions made by professional meteorologists on local weather reports. Knowledge of weather elements and patterns of change may lead to cautious weather predictions and perhaps an appreciation of the meteorologist's problems in predicting weather change exactly and consistently.

Section Eight:

The Changing Atmosphere

WEATHER MODIFICATION

"Curt flew into the cloud and started the dispenser in operation. I dropped about three pounds (of dry ice) and then swung around and headed south.

"About this time I looked toward the rear and was thrilled to see long streamers of snow falling from the base of the cloud through which we had just passed. I shouted to Curt to swing around and as we did so, we passed through a mass of glistening snow crystals!...We made another run through a dense portion of the unseeded cloud, during which time I dispensed about three more pounds of crushed dry ice...This was done by opening the window and letting the suction of the passing air remove it. We then swung west of the cloud and observed draperies of snow which seemed to hang for 2-3000 feet below us and noted the cloud drying up rapidly, very similar to what we observe in the cold box in the laboratory...

> While still in the cloud, as we saw the glinting crystals all over, I turned to Curt and we shook hands as I said, "We did it!" Needless to say, we were quite excited.
>
> "The rapidity with which the CO_2 dispensed from the window seemed to affect the cloud was amazing. It seemed as though it almost exploded, the effect was so widespread and rapid...
>
> "When we arrived at the port, Dr. Langmuir rushed out, enthusiastically exclaiming over the remarkable view they had of it in the control tower of the G-E Lab. He said that in less than two minutes after we radioed that we were starting our run, long draperies appeared from the cloud vicinity."

That is the way Dr. Vincent Schaefer described one of the most dramatic moments in the developing science of weather modification. Dr. Schaefer's attempt was not a lucky accident. He knew what was likely to happen and why the addition of dry ice to a cloud might cause snow to form.

Early attempts at weather modification were haphazard. People had vague feelings that if giant cannons were fired rain might fall. People who attempted to relate their cannons and other rainmaking devices to changes in the weather had incomplete or incorrect ideas of the causes of rain.

An understanding of weather begins with careful observation. ("The temperature is now 24 degrees with wind from the . . .") The next step is the development of models which are consistent with observations and are useful in understanding past weather. ("Yesterday's showers

resulted from a . . .") The third step is prediction. ("Lower temperatures are expected, ranging from . . .") The final step involves modification. Avoiding unintended, unwanted modification of weather is even more desirable than improvement of existing conditions.

In the next investigations you will find ways to make accurate observations of existing conditions. You will have an opportunity to develop models. Your ability to predict weather may be improved. You may even be able to modify the "weather" in small volumes of air.

INVESTIGATION 8.1: Using a Thermometer

Air temperature is a fundamental characteristic of the atmosphere. It is one of the things which is usually stated when the condition of the atmosphere is described. You are already familiar with measurement of water temperatures. Now you will start a series of air temperature measurements.

Materials (per team)

Thermometer

Procedures

A. Prepare a chart similar to Figure 8.1. Follow the instructions given by your teacher concerning details of the chart.

DATE	TIME	AIR TEMPERATURE °C

Figure 8.1.

B. Read the thermometer and record the air temperature of your classroom. Make your reading as accurate as possible.

C. Compare your reading with those taken in different parts of the room.

Interpretations

1. Explain any differences between your readings and those taken by other teams.

Procedures (continued)

D. Discuss with your class a way to select an "official" thermometer and outdoor site for air temperature readings.

PROBLEMS

1. When measuring the air temperature why should the thermometer not be in direct sunlight?

ADDITIONAL ACTIVITIES

1. Keep a record of the outdoor air temperature as measured each day in the same place and at the same time. Compare your record with those of other observers. Plot your data on a graph.

2. Keep a record of the temperature as measured every hour throughout most of a day. Compare your record with those of other observers. Plot your data on a graph.

3. Early in the morning take a series of temperature readings at different locations around your home or school. Or in the same location take a series of readings ranging from close to the ground to the top of a step-ladder. Try to account for any differences noticed.

TEACHER MATERIAL

INVESTIGATION 8.1: Using a Thermometer

Materials

Thermometers should be inexpensive ones filled with either alcohol or mercury. If you are using mercury type thermometers, caution students against handling mercury in the event that a thermometer is broken. Celsius thermometers are preferable over those marked in Fahrenheit, though either type will do.

Procedures

A. A sample chart is shown in Figure T-8.1. This chart has space for additional columns for data on wind, pressure, and other weather elements, which students will start recording in future investigations. You may wish to have students allow space for these columns on their temperature charts, or you may wish to have them keep additional data on separate sheets. A classroom size wall chart could be made on which observations are entered daily. The chart shown provides space for readings made at three different times each day. This anticipates that some students will make observations before school, others during class time or at noon recess, and others after school. Some students may wish to make records of temperatures given in newspapers or on television weather reports. As new elements are considered, different teams could be assigned to collect data related to the various elements. From

these data students can begin to correlate changes in one element with variation in others. When trends become recognized, the next step, weather prediction, should be a useful activity for students to attempt. The final activity in this section deals with analysis of weather data.

B. Temperature readings should be expressed in degrees Celsius.

C. There will probably be slight differences between readings of different teams.

Interpretations

1. Differences may be due to error in reading the thermometer, error in the thermometer itself, or actual temperature differences in various parts of the room. You may want to have students take readings in different parts of the room with the same thermometer to verify their answers. Also, placing all the thermometers in one place should reveal thermometer error.

<u>Procedures</u> (continued)

D. An average temperature can be determined from readings of several thermometers in the same location. The single thermometer nearest the average can then be selected as the official instrument. The outdoor site should be in an open but shaded place. (See Problem 1 below.)

PROBLEMS

1. The temperature shown by a thermometer held in the sun will generally be higher than the air temperature. The amount of difference depends upon the particular type of thermometer used. By convention, all air temperature measurements are read in the shade.

ADDITIONAL ACTIVITIES

1. If several students take readings at the same time of day their reading can be averaged. If one or more students take the temperature at each of the three times suggested, their data can be announced during class each day for use by the rest of the students. Encourage students whose homes have thermometers to make early morning and late evening readings. The purpose of the activity is to build up temperature records which can later be correlated to other weather elements, such as cloud type and wind direction.

Suggest standard time scales (such as 1cm/day) to be used in constructing all graphs of weather phenomena. The time scale should run horizontally and the other scale (temperature, barometric pressure, etc.) vertically. This will allow for easier comparison of graphs and correlation of observations.

2. The purpose of this activity is to establish a background of normal changes in temperature throughout a day. A student who knows from such an activity what sorts of temperature variations to expect is more likely to recognize unusual changes in temperature which accompany changes in the weather.

3. The activity should be conducted early in the morning, since air is more likely to be unmixed at that time. Temperature differences of several degrees can often be detected at points only a few meters apart. Encourage students to speculate on causes of any temperature variations noticed.

RECORD OF WEATHER ELEMENTS

DATE	TIME	AIR TEMP	WIND DIRECTION and SPEED	AIR PRESSURE	RELATIVE HUMIDITY	AMOUNT and TYPE of CLOUD COVER	AMOUNT and TYPE of PRECIPITATION
12/11	8:00 am	14°C	S-10 mph	29.1 in	65%	.5 Stratus	None
	1:00 pm	15°C	SE-15 mph	29.0 in	70%	.8 Nimbostratus	Trace-rain
	4:00 pm	14°C	SE- 5 mph	28.9 in	70%	1.0 Nimbostratus	1/4 inch-rain

Figure T-8.1.

OPTIONAL INVESTIGATION: Dust in the Atmosphere

Air pollution is a much discussed topic. The particles of matter that are released into the atmosphere are one form of air pollution. In this investigation students determine the amount of particle fallout from the atmosphere. Because of the need for a balance which might not be available in every class, and because of possible difficulties in scheduling, the investigation is listed as optional.

Materials

Scale, sensitive to .01g
Glass plate, 2" x 6" or microscope slides, 1" x 3"
Petroleum jelly
Masking tape

Procedures

A. Place four microscope slides on a flat surface so that they form a rectangular plate. Tape the slides together to form a single unit 4 x 6 inches.

B. Find the area of the plate (multiply length x width) and record this in your notebook.

C. Apply a smooth, even coating of petroleum jelly to the taped surface of the plate.

D. Weigh and record the weight of the coated plate to the nearest hundredth of a gram. Be careful not to touch the coating once you have made your weighing!

E. Set the plate (coated side up) out in a place where it will not be disturbed. Make sure that there are no obstructions (trees, roof, porch, etc.) directly <u>above</u> the plate. A rooftop is an excellent place to set the plate. It should be placed so that the plate is lying in a flat, horizontal position.

F. Expose the plate for 15 days. If rain or snow is expected, bring the plate in so that no precipitation washes the coating. Replace the plate after the storm passes.

G. After fifteen days of exposure, return the plate to the classroom and record its weight.

H. Determine any change in weight that has occurred during the exposure time. Record your answer.

Interpretations

1. How much dust has fallen out of the atmosphere onto your plate during the exposure time? (Responses will vary. A typical amount would be .05g.)

<u>Procedures</u> (continued)

I. Particle pollution fallout is often recorded as weight of fallout/square mile/month. If your glass plate had an area of one square mile and you left it out for a month you could arrive at an answer by simply determining the change in weight of the square mile plate. Since this is impractical,

small sample plates such as the one you set out are used. The small sample fallout figure is then converted to the weight/square mile/month figure.

J. To find the fallout per square mile per month, multiply the gain in weight x 1,472,000. Your answer will be in pounds of fallout per square mile per month.

Interpretations

2. How much fallout per square mile per month does your sample indicate for your area? (A typical value would be 73,500 pounds/square mile/month.)

3. What sources of particle pollution exist in your community? (Answers will vary.)

4. What time of year do you think the atmosphere would contain the most particle pollution? Explain. (Summer because in general there is less rainfall and the air contains more particulate matter.

INVESTIGATION 8.2: An Effect of Heating

Materials

- Shoe box
- Saran wrap
- Aluminum foil
- 2 cylindrical cardboard tubes
- Sheet of black construction paper
- Short candle
- Paper towel
- Matches
- Scissors
- Masking tape
- Scotch tape

Procedures

A. Tape a piece of black construction paper in the bottom of a shoe box. Cut two openings about 15cm apart on one side of the shoe box just large enough for the tubes to fit.

B. Line one of the tubes with aluminum foil to make it fire-resistant. Tape the tubes in the openings as shown in Figure 8.2. They should extend about one centimeter into the box.

C. Cut a large rectangle out of the lid. Cover the hole with a piece of Saran Wrap taped to the lid.

D. Remove the lid and place a small lighted candle under the foil-lined chimney. Close the lid.

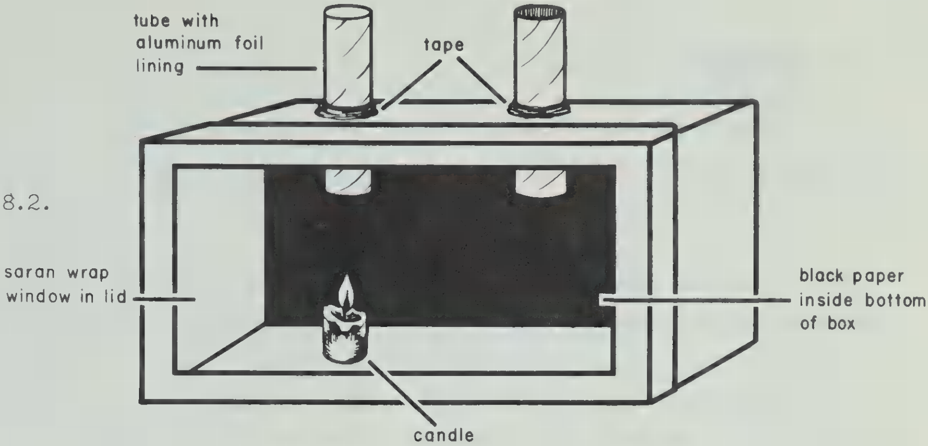


Figure 8.2.

E. Moisten a rolled paper towel slightly, light it with a match, and blow out the flame. Hold the smoking paper over the chimney above the candle.

Interpretations

1. Describe the results of Procedure E.

<u>Procedures</u> (continued)

F. Repeat Procedure E, but hold the smoking paper above the other chimney.

Interpretations

2. Describe the results of Procedure F.

3. Account for any differences observed in the results of Procedures E and F.

The device you have been observing is a convection box. Behavior of the earth's atmosphere can be compared to air currents in the box.

Interpretations

4. Where do you think rising air would be more likely to be found, over a warm area of the earth's surface or over a cool area?

5. Do you think winds are more likely to blow toward a warm area or toward a cool area?

6. In this investigation a candle caused air to be warmed. What do you think heats different parts of the earth's atmosphere?

TEACHER MATERIAL

INVESTIGATION 8.2: An Effect of Heating

Materials

Cylinders from toilet tissue can be used for the chimneys.

Procedures

A. Tracing the outline of the tube on the side of the box should help in cutting a hole the right size for a snug fit.

B.-E. No comment.

Interpretations

1. The heated air rising above the candle causes the smoke from the towel to rise.

Procedures (continued)

F. No comment.

Interpretations

2. The smoke should be seen to pass down through the chimney over which it is held, along the bottom of the box, and up through the chimney above the candle. The black paper makes the path of the smoke more easily visible.

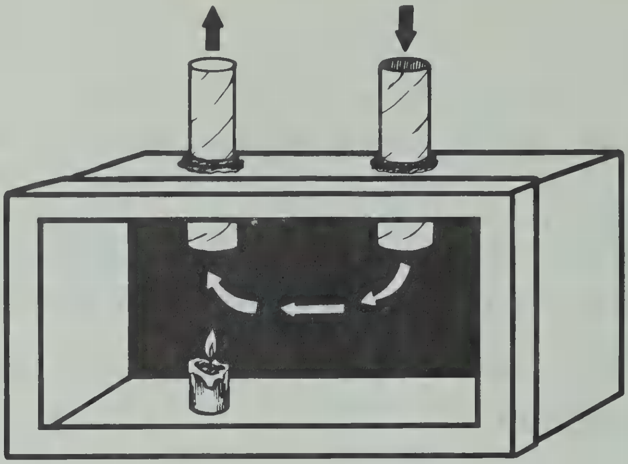


Figure T-8.2.

3. The air near the candle is heated and becomes less dense. Cool air in the other chimney is more dense than the warmer air. The cooler air descends, forcing the warm air out through the chimney over the candle.

4. Rising air is generally found over warmer parts of the earth's surface.

5. Winds have a tendency to blow toward warm areas, i.e. areas of low pressure.

6. The earth's surface is warmed by sunlight which strikes it.

Air adjacent to the earth's surface is warmed by it. Different parts of the surface are warmed by different amounts giving rise to varying air temperatures. The warmer bodies of air tend to have lower pressure than do cooler bodies. This line of reasoning leads to the next topic, direct measurement of pressure differences in the atmosphere.

TEACHER MATERIAL

INQUIRY DEMONSTRATION: The Aneroid Barometer

The pressure of the atmosphere on people and on objects at the surface of the earth is so constant that it is not easy to recognize that it exists. The pressure becomes noticeable only when a person changes elevation rapidly and his ears "pop." Minor variations in pressure are very important in anticipating and explaining weather changes. Barometers, devices which can detect these minor variations, are of two types: mercury and aneroid.

Mercury barometers are easy to construct but are not recommended because of the health hazards associated with the handling of mercury.

The purposes of this demonstration are to show the existence of air pressure and to develop the principles of the aneroid barometer.

Materials

- Empty ditto fluid can
- 1-hole stopper to fit
- Short length of glass tubing
- 10 feet of rubber tubing
- Dishpan or bucket (2-quart capacity)
- String
- Aneroid barometer
- Support for can
- Water glass
- File card

During the demonstration the can is to be placed 2m or more above the floor of the room. If there is no shelf, bracket or other attachment at this height in your room you may wish to borrow a step-ladder.

Before class, assemble the glass tubing, rubber tubing, and stopper as shown in Figure T-8.3. Place the dishpan on the floor under the support for the can.

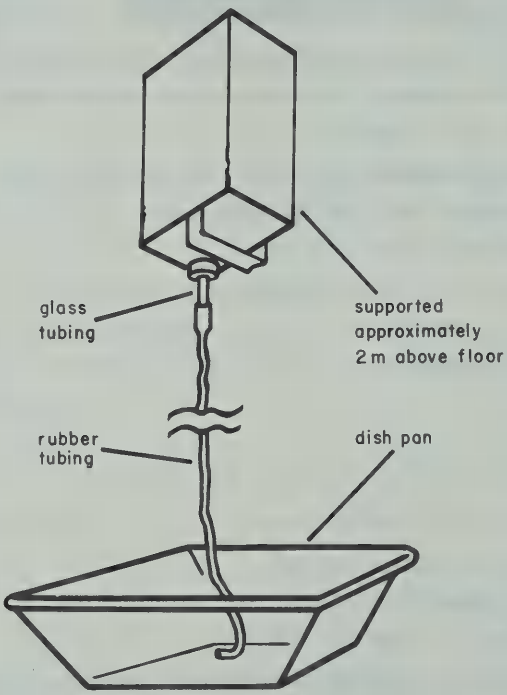


Figure T-8.3.

Procedures

Lift the can, apparently with some effort. Ask the students whether they think it is full or empty, what it is filled with, etc. Remove the lid, invert the can and show that it has nothing in it. However do not agree that it is empty. Be non-committal.

Fill the can with water. Completely fill the tubing with water and tie or clamp the end so that no water will be lost. Insert the stopper with tubing attached. Ask the class what they think will be done with the apparatus.

Raise the can to 2m or more above the floor. Place the can in position, top down, with as much of the can in view as possible. It is not possible to predict which side of the can will collapse. Ask students what they think will happen if you open the end of the tubing. (Some will probably predict, correctly, that the water will run out.)

Open the end of the tubing; allow students to see that water does run out of it. Place the end of the tubing in the dishpan. Call attention to the can. As water runs from it, the can will very slowly and dramatically be crushed.

Ask the students for observations, predictions as to how far the can will be crushed, etc. Focus attention on responses involving words such as "crush" and "squeeze." Such responses are likely, since the can does indeed give the appearance of being crushed. Try to avoid using terms such as "vacuum," "suction," and "collapse," as these words draw attention to the inside of the can.

Depending on the particular can used and the height at which it was suspended, the crushing will go on to a greater or lesser extent. After the can has been reduced to half its original volume or less, lower the can from its support and empty the last of the water from it. Hold it up for inspection and invite suggestions as to what has happened. (Again concentrate on words such as "crush.") What caused the "crushing"? (The weight or pressure of the atmosphere.) Why wasn't the can crushed when it was first shown? (There was air pressure inside it pushing out.) Then was it really

"empty"? (No.) Why did the <u>side</u> of the container get pushed in? (That is where the pressure came from.)

State that if air pressure really did crush the can it should be possible to "uncrush" it with air pressure. Re-insert the stopper and invite one of the students to blow into the tube. (Hard blowing should partially restore the can.) Why can't the can be totally brought back to shape? (Air pressure from the atmosphere must be greater than the pressure developed within the lungs.) Why is it necessary for a deepsea diver to breathe compressed air as he descends? (Water pressure added to atmospheric pressure would otherwise tend to compress his body.)

Hold the file card by one end in front of the class horizontally. Ask why the weight of the atmosphere doesn't push the other end downward. (There is also pressure pushing up on its lower surface.) If there is such pressure, it should be possible to demonstrate it.

Fill a drinking glass completely full of water. A beaker will not work for this demonstration because its pouring lip breaks the regular outline of the rim. Place the file card on the glass and hold it in place. Invert the glass and remove the hand which supports the card. Ask what is happening. (Air pressure pushes the card upward with greater force than the weight of the water exerts downward.)

Exhibit the aneroid barometer. Explain that it contains a "can similar to the one you saw." The can has had the air removed from it. Why do you suppose this is necessary? (So that temperature changes will not cause the "can" to expand and contract.) Why does the can not collapse? (It has been made strong enough not to. Its small size reduces

the total force against it.) What would slight increases in atmospheric pressure do to such a can? (They would cause its volume to be reduced slightly.) What would happen if the atmospheric pressure decreased slightly? (The springiness of the metal would cause the can to increase in volume.)

Explain that these slight changes in volume, resulting from pressure changes, are indicated by the pointer on the barometer. If a classroom barometer is available, encourage students to read it several times a day and record or plot readings for later analysis. If a classroom barometer is not available, newspaper or television weather reports can be watched for the data needed. In some cities recorded weather conditions and predictions may be obtained by telephone.

INVESTIGATION 8.3: Heating Land and Water

Materials (per team)

Ring stand and ring
2 beakers or jars
Soil or sand
2 thermometers
Flood light

Procedures

A. Label the beakers A and B. Fill beaker A with soil to within one centimeter of the top. Fill beaker B with water at room temperature to within one centimeter of the top.

B. Copy Figure 8.3 in your notebook.

Figure 8.3.

TIME	SOIL TEMP	WATER TEMP
Start		
5 min		
10 min		
15 min		
20 min		

C. Place beakers A and B side by side on your desk or table. Position the flood light about 20cm from the beakers so that the surfaces of the contents of each beaker will be lighted equally.

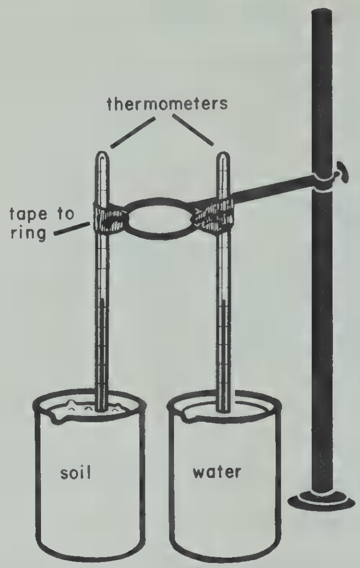


Figure 8.4.

D. Suspend the thermometers from a ring stand so that their bulbs are just below the surface of the soil and the water (as shown in Figure 8.4). Read and record the temperature shown by each in the chart on the line labeled START.

E. Turn on the flood light. After five minutes, read and record the temperatures. Repeat temperature readings at five-minute intervals for a total of twenty minutes.

Interpretations

1. How many degrees temperature change occurred in the soil during the twenty-minute interval? In the water?

2. What is the average temperature change per five-minute interval in the soil? In the water?

3. What do the results of this investigation suggest about the daytime air temperatures over land and ocean along a coast line in the summer?

4. What kind of daytime wind patterns would you expect to find along a coast in the summer?

FOR FURTHER ACTIVITY

1. Design and carry out an investigation to find out the <u>cooling</u> rates of land and water.

Problems

1. How would heating rates of earth and water affect coastal wind patterns at night?

2. How would heating rates of earth and water affect oceans and continents during winter?

TEACHER MATERIAL

INVESTIGATION 8.3: Heating Land and Water

Materials

Dry garden soil or sand give good results.

If flood lights are not available, placing the beakers outdoors in direct sunlight gives even better results.

Procedures

A. Allowing the water to stand overnight in a closed container will ensure that the soil and water will be at the same "starting" temperature.

B. No comment.

C. The light should strike the surfaces at about a 45° angle.

D.-E. No comment.

Interpretations

1. Sample results are: soil temperature increases about $6^{\circ}C$ while water temperature increases about $3^{\circ}C$.

2. Soil temperature increases about $1.5^{\circ}C$ every five minutes; water temperature increases about $.75^{\circ}C$ every five minutes.

3. Daytime air temperatures over land will be higher than air temperatures over water.

4. On-shore breezes are found along temperate coasts in the summer. Descending air over the cooler water moves shoreward to replace warmer air rising over the land.

FOR FURTHER ACTIVITY

Students can use a similar experimental design to heat the soil and water, remove the heat or light source, and record cooling rates.

Problems

1. At night when the land is cooler than the ocean, off-shore breezes are produced.

2. Similar effects on a larger scale occur on a seasonal basis. Strong heating of the inland areas produces low pressure centers over continents during the summer. In winter the continents cool more rapidly than do the oceans. High pressure centers develop over continents and low pressure centers over oceans.

INVESTIGATION 8.4: Wind Direction and Speed

Wind direction and speed are two important elements to be considered when weather is being analyzed. Changes in wind speed and direction are often useful as indications of approaching weather conditions. Winds are "named" according to the direction of their origin. A north wind, for example, blows from the north toward the south.

Materials (per team)

Wire coat hanger
Wire cutter
5" x 6" file card
Scissors
Thread
Paper clips
Magnetic compass

Procedures

A. Cut out the twisted portion of the coat hanger by making two cuts, one on each side of the base of the handle.

B. Bend the remaining wire to form a frame similar to that shown by the broken lines in Figure 8.5.

C. Cut the file card to the shape shown in the figure. The narrow end should be 2.5cm wide, and the wide end 10cm across.

D. Tie the end of a 25cm piece of thread to one end of the wire frame. Loop the thread around the other side. Pull the two sides together until

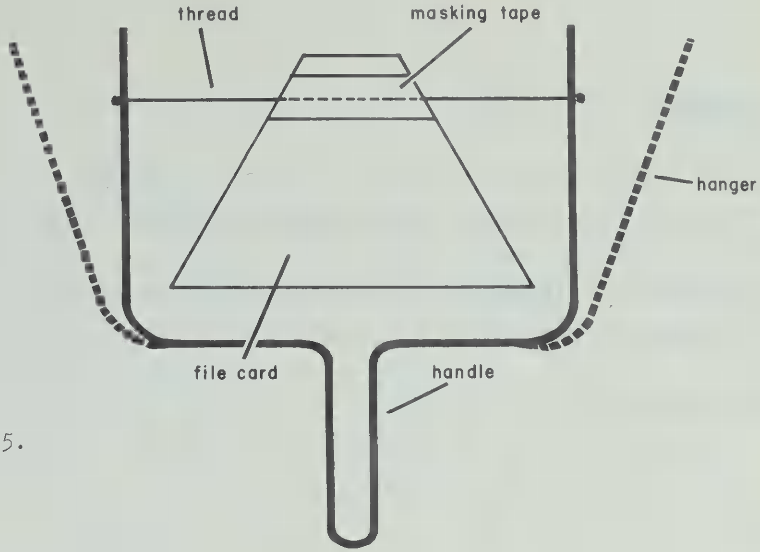


Figure 8.5.

the frame is in the shape shown by the solid lines in Figure 8.5. Tie the thread so that the frame is held in this position.

E. Tape the card firmly to the thread at a point 3.5cm from the narrow end of the card as shown in Figure 8.5.

F. Take the apparatus and a magnetic compass outside to a place where a breeze is blowing. Hold the frame so the thread is in a vertical position. Using the compass, determine the direction from which the wind is blowing. Compare your answer with those obtained by other teams.

Interpretations

1. From what direction is the wind blowing?

2. How is such a wind described?

3. Account for any differences in wind direction determined by other teams.

Procedures (continued)

G. Hold the frame so the thread is in a horizontal position and a flat side of the card faces the wind. If the card is deflected more than 45° add paper clips to the wide end until the card is deflected at about a 45° angle.

Interpretations

4. How many paper clips were needed to obtain a 45° deflection?

FOR FURTHER ACTIVITY

Design and carry out an experiment to convert number of paper clips needed to maintain a 45° deflection angle of the wind speed indicator to wind speed in miles per hour.

INVESTIGATION 8.4: Wind Direction and Speed

After constructing the wind vane-anemometer, students can take regular readings to add to their weather analysis charts.

Materials

No comment

Procedures

A.-B. Caution students not to cut themselves on the sharp ends of the coat hanger.

C. No comment.

D. It is important that the thread hold the wire frame under tension.

E. The thread must be taut and the card taped securely to it. The card will then remain straight when the frame is held with the thread vertical.

F. Wind directions near buildings or other large objects tend to be quite erratic due to local drafts and currents.

Interpretations

1. Answers will vary. Students should realize that the small end of the card points to the source of the wind.

2. Answers should be the same as those given for Interpretation 1.

3. Large objects produce eddy currents in moving air.

Procedures (continued)

G. Recording wind speed as a "two clip wind, or three clip wind" can give worthwhile comparisons of wind speed on successive days.

Interpretations

4. Answers will vary.

FOR FURTHER ACTIVITY

The wind speed indicator can be calibrated by recording deflection angle (or paper clip number) and speedometer readings in a moving automobile while holding the indicator out the window. Such calibrations should be made on a calm day.

Bicycles with speedometers may also be used.

Speeds of up to 10-15 miles per hour may be attained by running.

Students may have to be told that moving the wind vane through still air at 10mph produces the same effect as holding the vane stationary in a 10mph wind.

INVESTIGATION 8.5: An Effect of Cooling

In previous investigations you have considered temperature and its effects on air. There seems to be a relationship between temperature, air density and winds.

Now you will investigate an effect of temperature on the composition of air. By changing temperatures you may find evidence for an important component of the atmosphere.

Materials (per team)

2 beakers
Ice

Procedures

A. Label the beakers A and B. Half fill beaker A with ice and add just enough water to float the ice.

B. Half fill beaker B with water at room temperature.

C. Wipe dry the outside of both beakers. Observe the outside of the beakers closely for several minutes. Describe and record any changes you see. Be careful to note the appearance of any "new" substances on the beakers.

Interpretations

1. Did any "new" material form on the outside of beaker A or B? If so, which one(s)?

2. Does the "new" material resemble water?

3. Assuming it is water, where do you think it came from?

4. What differences are there in the contents of beaker A and B?

5. What differences do you think there are in the temperatures of the air that immediately surrounds beaker A and the air around beaker B?

Procedures (continued)

D. Observe the flask of boiling water that has been set up. Look closely at the space just above the hole, taking care not to get burned. Make a sketch of what you see near the top of the flask.

Interpretations

6. The fog that you may see near the hole consists of small droplets of liquid water. Where do you think this water came from?

7. What evidence do you have to suggest that water may exist in a form that cannot be seen?

ADDITIONAL HOME ACTIVITY

Procedures (continued)

E. Observe the cold unit of a refrigerator which has not been defrosted recently.

Interpretations

8. Is there any evidence of moisture on the freezing unit?

9. If so, in what form is the moisture?

10. How did it get where it is?

Procedures (continued)

F. Place a measured one-half cup of water in a dish. A relatively flat dish is preferable to a deep one. Place dish and water in a place where it will not be disturbed for 24 hours. Do not place a cover over the water.

After 24 hours measure the remaining water.

Interpretations

11. How much water is left?

12. How much water disappeared?

13. What happened to the water which disappeared?

Procedures (continued)

G. On a cold day watch your breath form a mist.

Interpretations

14. Why is your "breath" visible?

15. In what form is the water in your breath when it is visible?

16. Why do you think your breath cannot be seen on warm days?

INVESTIGATION 8.5: An Effect of Cooling

Students observe the "disappearance" (evaporation) of liquid water and in other places observe the appearance (condensation) of visible water. It is to be inferred that in between, the water was present but in an invisible form.

The situation is somewhat analagous to that of a rifle bullet. The bullet in flight cannot be observed directly. Instead, it is observed before firing and again after it has stopped. It is reasonable to assume the bullet continued to exist, even when it could not be seen.

The students should also observe that temperature changes are related to the appearance and disappearance of liquid water.

Materials (for teacher demonstration)

Erlenmeyer flask
One-hole stopper
Heat source
Ring stand

Procedures

A.-C. No comment.

Interpretations

1. Yes, droplets appear on beaker A. The time required for them to form will depend upon the room temperature and the water vapor content of the air (the relative humidity).

2. Yes, the new material looks like water.

3. The water came from the air. If there is a tendency on the student's part to raise the problem of possible seepage or leakage, they should be asked to account for the absence of water on beaker B. Some students, however, may continue to believe that seepage is occurring. If so, experiments with cans (sealed) of everything from dog food to ravioli may be conducted. Regardless of contents of can, liquid water forms on the outside if the can has been chilled. Even solid cans (i.e. blocks of metal) will show condensation if refrigerated and then exposed to the air.

4. The contents of A are colder than B.

5. The temperature of the air near A will be colder than the air around B.

<u>Procedures</u> (continued)

D. Half fill a flask with water and fit it with a one-hole stopper. Bring the water to a slow boil. Caution students about the danger of burns from the escaping steam. A short distance from the spout (the hole in the stopper) a cloud may appear. Between the spout and the cloud is a space in which nothing can be seen.

Interpretations

6. The water in the cloud came from the flask.

7. The cloud must have come from the flask. Between the flask and the cloud there was a space in which nothing could be observed. It seems likely that there was water in this space. It simply was in an invisible form.

ADDITIONAL HOME ACTIVITY

Procedures (continued)

E. No comment.

Interpretations

8. Yes, there should be evidence of moisture on the freezing unit.

9. It was solid (ice).

10. Before freezing onto the unit the water was in the form of water vapor. Some of this may have evaporated from unwrapped foods in the refrigerator. The rest entered as part of the air that came in each time the refrigerator door was opened.

Procedures (continued)

F. No comment.

Interpretations

11. Answers will vary.

12. Answers will vary.

13. The water that disappeared changed into water vapor. This procedure is perhaps more convincing than Procedures C and D because of the lack of obvious clouds of re-condensed liquid water. However, it takes more time.

Procedures (continued)

G. No comment.

Interpretations

14. Water vapor in the breath is condensing into visible droplets of liquid water.

15. When water in the breath is visible it is in the form of droplets of liquid water.

16. The water vapor does not condense into visible droplets of liquid water. This suggests the important idea that the ability of the air to contain water vapor is related to the temperature.

INVESTIGATION 8.6: Finding the Dew Point

The procedures in the last investigation were designed to help show you that under certain conditions, liquid water may "disappear" (evaporate) into the air. When this happens, it changes from a liquid to an invisible gas called water vapor. At other times, water vapor in the air condenses (joins together) to form drops, and liquid water "appears" out of the air. One of the conditions that affects these processes is air temperature. If air (containing water vapor) is cooled, there will be a point reached at which the water vapor in the air begins to condense and form a liquid. In a volume of air, the temperature at which water changes from a gas to a liquid is called the dew point.

In this investigation you will determine the dew point in your classroom.

Materials

- Thermometer
- Tin can
- Water (at room temperature)
- Ice
- Stirring rod
- Towel

Procedures

A. Remove the label from a tin can. Add water that is at room temperature (or warmer) until the can is half full. Wipe dry the outside of the can with a paper towel. Place the thermometer in the can.

B. Add a few small pieces of ice while stirring the mixture. Use a stirring rod rather than your thermometer to mix the ice and water.

Other members of your team should carefully observe the outside of the can. After a minute or two, add another piece of ice, stir and wait. Repeat this process until dew is observed. At the first signs of water droplets or dew, read the thermometer. Record the water temperature in your notebook.

Interpretations

1. Assuming that the air immediately surrounding the can was at the same temperature as the contents, what is the dew point temperature of the air in your classroom? Compare this with readings found by other teams.

2. If all the air in the classroom were cooled to its dew point, what would you expect to see?

<u>Procedures</u> (continued)

C. Repeat this activity to find the dew point outdoors.

INVESTIGATION 8.6: Finding the Dew Point

Materials

Shiny tin cans work best for this investigation.

Procedures

A. No condensation should appear if the water is the same temperature or warmer than the air.

B. If the air is very dry, the dew point may be below freezing. The addition of salt to the ice and water will further lower its temperature.

Interpretations

1. Answers will vary.

2. Fog would appear in the room.

Procedures (continued)

C. You may want to send only one team outdoors to do this activity, rather than the entire class.

INVESTIGATION 8.7: Measuring Relative Humidity

You have found that air contains water vapor. The rate at which liquid water changes to water vapor is affected by the temperature. You will now investigate another factor which affects the rate at which water will evaporate.

Materials (per team)

- Thermometer
- Small piece of cloth
- Water
- File card
- Rubber band

Procedures

A. Hold out two fingers of one hand. Fan the fingers with a file card.

Interpretations

1. What sensation of temperature do you notice?

Procedures (continued)

B. Moisten one of the two fingers in water. Again fan the two fingers with a file card.

Interpretations

2. What difference in temperature is noticed in the wet and the dry fingers?

3. How do you account for this difference?

Procedures (continued)

C. Hold the two fingers about 5cm in front of your mouth. Blow first on one finger and then on the other.

Interpretations

4. What difference do you notice between results of Procedures B and C?

5. How do you account for this difference?

Procedures (continued)

D. Read the thermometer and record the temperature shown by it in your notebook. Label the reading "dry bulb." Fan the thermometer with the file card for about one minute. Read and record the temperature a second time.

Interpretations

6. What difference, if any, was there in the two thermometer readings?

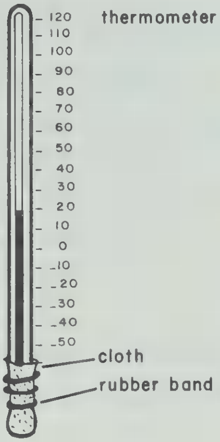
7. Why do you think the thermometer behaved as it did when it was fanned?

Procedures (continued)

E. Cover the bulb of the thermometer with a single thickness of cloth. Fasten the cloth in place with a rubber band as shown in Figure 8.6.

Moisten the cloth and fan the thermometer for one minute. Record the temperature in your notebook. Label this reading "wet bulb."

Figure 8.6.



Interpretations

8. What is the temperature difference between the dry-bulb reading (Procedure D) and the wet-bulb reading (Procedure E)?

<u>Procedures</u> (continued)

F. Figure 8.7 is a chart of relative humidities. Use the temperature difference you found in Interpretation 8 to enter the chart from the top. Use the dry-bulb thermometer reading to enter the chart from the left. The number in the chart found at the intersection of the two entries is the relative humidity.

Interpretations

9. What is the relative humidity as shown by the chart?

Figure 8.7.

DIFFERENCE BETWEEN DRY-BULB AND WET-BULB TEMPERATURES ($^{\circ}C$)

DRY-BULB TEMPERATURE $^{\circ}C$	1	2	3	4	5	6	7	8	9	10
- 4	77	55	33	12						
- 2	79	60	40	22						
0	81	64	46	29	13					
2	84	68	52	37	22	7				
4	85	71	57	43	29	16				
6	86	73	60	48	35	24	11			
8	87	75	63	51	40	29	19	8		
10	88	77	66	55	44	34	24	15	6	
12	89	78	68	58	48	39	29	21	12	
14	90	79	70	60	51	42	34	26	18	10
16	90	81	71	63	54	46	38	30	23	15
18	91	82	73	65	57	49	41	34	27	20
20	91	83	74	66	59	51	44	37	31	24
22	92	83	76	68	61	54	47	40	34	28
24	92	84	77	69	62	56	49	43	37	31
26	92	85	78	71	64	58	51	46	40	34
28	93	85	78	72	65	59	53	48	42	37
30	93	86	79	73	67	61	55	50	44	39
32	93	86	80	74	68	62	57	51	46	41
34	93	87	81	75	69	63	58	53	48	43
36	94	87	81	75	70	64	59	54	50	45

Relative Humidity (%)

Problems

1. Why do you think you were instructed to fan the thermometer in Procedure E instead of blowing on it?

2. Why do you think people fan themselves in warm weather?

3. Suppose the temperature in your classroom stayed the same as the reading you made in Procedure D, but the amount of water vapor in the air increased.

   a. Would this cause a greater or smaller difference in temperature between dry-bulb and wet-bulb thermometers?

   b. As shown by the chart, would the relative humidity be greater or less than the actual measurement you made?

4. What do you think the relative humidity would be if the air in the room was cooled to the dew point?

5. Why do cooking pots frequently have lids?

TEACHER MATERIAL

INVESTIGATION 8.7: Measuring Relative Humidity

The rate at which water evaporates increases with increasing water temperature. It also increases as the amount of water vapor in the air (relative humidity) decreases. In this investigation students will determine the relative humidity by observing the cooling effect of evaporation.

Materials

Thread may be substituted for the rubber band.

Cotton cloth is preferable to synthetic fabric in this application.

Procedures

A. No comment.

Interpretations

1. The fingers feel cooler when fanned.

Procedures (continued)

B. No comment.

Interpretations

2. The wet finger feels noticeably cooler than the dry finger.

3. Answers will vary. Encourage speculation. Actually, fanning carries away molecules of water vapor before they have a chance to "fall back" to the liquid phase. The molecules which are removed tend to be the more energetic ones. The molecules left behind are those with less energy (lower temperature), so the wet surface feels cooler. At the student level, a recognition that evaporation produces a cooling effect is sufficient.

Procedures (continued)

C. No comment.

Interpretations

4. The dry finger is cooled very little, and the wet finger somewhat, but not as much as when fanned.

5. The breath is very humid. Water will not evaporate into it at a very great rate. Therefore little evaporative cooling occurs. Of course the breath is also warmer than room air and this may decrease the cooling effect.

Procedures (continued)

D. No comment.

Interpretations

6. There is no difference between the readings.

7. Since there was no moisture to evaporate, the thermometer would not be cooled by fanning.

<u>Procedures</u> (continued)

E. One minute of fanning should be sufficient. If the temperature of the wet-bulb thermometer is still dropping, the fanning should be continued till the lowest possible reading is obtained.

Interpretations

8. Responses will vary.

<u>Procedures</u> (continued)

F. No comment.

Interpretations

9. Responses will vary.

Problems

1. The aim of the procedures is to determine the relative humidity of room air. Blowing on the thermometer would result in readings reflecting temperature and relative humidity of the breath.

2. Even though people are not always conscious of perspiration, the skin is slightly moist. Fanning evaporates this moisture and produces a cooling effect.

3. a. With more water vapor in the air, cooling due to evaporation would be less pronounced and there would be less difference.
   b. A smaller temperature difference reflects a higher relative humidity.

4. The relative humidity is 100% at the dew point.

5. When the air between liquid and lid reaches 100% relative humidity no more evaporation of liquid can take place. The temperature of the substance being cooked rises, and water loss is decreased.

Relative humidity is an expression of the ratio of the amount of water vapor in the air (humidity) to the amount of water vapor that air at that particular temperature could hold if saturated. For students, it is sufficient to know that relative humidity expresses the dryness or moistness of the atmosphere.

Students should be encouraged to determine relative humidity daily, recording values with other weather data.

INVESTIGATION 8.8: Forming Clouds

Clouds are made up of large numbers of tiny drops of liquid water. Clouds form when conditions are such that water vapor will condense into liquid water.

What are the right conditions? In a previous investigation you observed that a lower temperature favors condensation.

In the classroom it is often difficult to cool air directly in order to produce clouds. You can, however, use a method which involves pressure changes to produce clouds.

You will also investigate other "conditions" of cloud formation.

Materials

2 glass bottles (1 quart or larger)
Matches

Procedures

A. Hold the bottle mouth down so that the inside of the bottle will not get wet. Wash the mouth of the bottle with soap and water. Rinse and dry.

B. Place your lips against the mouth of the bottle. Be sure to make a tight seal. Increase the pressure inside the bottle by forcing air into it. (Caution: Don't blow too hard; you could damage your ears!) Quickly remove your mouth from the bottle, allowing the pressure inside the bottle to drop suddenly to normal.

Interpretations

1. Was any fog or cloud observed in the bottle as the pressure dropped?

Procedures (continued)

C. Place about one tablespoonful of water in the bottle. Swirl the bottle to coat its walls with water. Repeat the process of increasing and decreasing the pressure within the bottle.

Interpretations

2. Was any fog or cloud observed?

3. If so, was the fog more or less noticeable than the fog (if any) of Procedure B?

Procedures (continued)

D. Be cautious in using and discarding matches. Follow your instructor's directions. Hold the bottle mouth down. Light a match. As soon as the tip of the match has finished flaring, blow the match out.

Allow a wisp of smoke from the match to enter the bottle. Repeat the process of increasing and decreasing the pressure within the bottle.

Interpretations

4. Was any fog observed?

5. If so, how does this fog compare to other fogs that may have been formed earlier?

<u>Procedures</u> (continued)

E. Rinse out the bottle and set it to drain. Let a little smoke into a thoroughly dry bottle. Do not, however, place any water in the bottle. Increase and decrease the pressure within the bottle.

Interpretations

6. Did a cloud form within the bottle?

7. What <u>three</u> conditions are needed for best formation of a cloud?

TEACHER MATERIAL

INVESTIGATION 8.8: Forming Clouds

Compressing a gas such as air causes its temperature to rise. If a tire pump is available it can be used to demonstrate this effect. The tube leading from the pump to, say, a football will be noticeably warmed as the pump is operated. Air escaping from a football or tire is cooled again as it expands.

In this investigation students will increase the pressure within a bottle by blowing into it. When the pressure is released the air remaining in the bottle will be cooled.

Materials

Quart size or larger bottles work best. Clear pop bottles are a possible substitute, but are not as satisfactory.

<u>Procedures</u>

A.-B. It would be better to wash the bottles ahead of time and allow them to drain before the class uses them. The intent is to show that little fog forms in a dry bottle. Of course, all air contains some water vapor, and so does the breath. This may provide enough moisture for cloud formation.

The clouds, if any, will be more easily visible if the room is darkened and the bottles lighted from the side.

Interpretations

1. There may or may not be a cloud.

Procedures (continued)

C. This procedure ensures that there will be sufficient water vapor within the bottle to produce a cloud.

Interpretations

2. Yes, a fog or cloud was observed.

3. The fog was more noticeable than the one seen in Procedure B.

Procedures (continued)

D. Before giving out matches it would be well to review safety procedures.

Interpretations

4. Yes, a fog was produced.

5. The cloud was more dense than those produced previously.

Procedures (continued)

E. The idea is, in this case, to have two conditions (smoke and pressure changes) present without the third (water vapor in the air). In earlier

procedures there were: first, pressure changes; then pressure changes and water vapor; and then pressure changes, water vapor and smoke.

If equipment is available, some students may wish to investigate the effects of producing pressure changes with a small hand pump rather than with the breath. This leads to a drier atmosphere within the bottle.

Interpretations

6. A cloud may form in the bottle but it should not be very dense.

7. For best results there should be pressure changes, plentiful water vapor, and smoke particles.

NUCLEI

Clouds are made up of drops of liquid water formed from invisible water vapor in the air.

Water drops are less likely to form in pure air than air in which small particles are present. Such particles are called "nuclei." Smoke is made up of large numbers of very small particles of solid material.

You may wonder why the solid material does not fall like most solids do. The answer is that the bits of solid material are so small that they can be held up by the air. Sometime, drop a sheet of paper and watch it fall. Then cut off a very small bit of paper (less than 1mm on a side). You should notice that it falls more slowly than a larger piece.

Single smoke particles are much smaller than the tiny bits of paper. Therefore it takes them longer to fall out of the air. Some would remain in the air indefinitely if it were not for rain.

Ordinary air contains a certain amount of water vapor. If the amount of particles in the air is increased it is more likely that water vapor will meet nuclei around which droplets of liquid water can form. When there are many nuclei, the water vapor will form many small drops of liquid water. These small drops may be so small that they do not fall. They will remain in the air as haze, making it difficult to see very far.

If there are only a few nuclei in the air, water vapor will not be able to turn into liquid water as easily. The air will remain clear until the atmosphere is cooled. The cooler air is less able to hold water vapor. The water vapor forms fewer, larger droplets, and these appear as clouds.

Further cooling may cause the cloud droplets to become large enough to fall. As they fall the drops will

collect more smoke particles and carry them to the ground. A rain is said to "scrub" the atmosphere of dust and smoke particles. For that reason it is often very clear just after a rain.

Sometimes rain falls in very tiny drops. Sometimes the raindrops are quite large. If there are few nuclei in the air, drops tend to be larger.

Smoke is not the only source of nuclei for rain or cloud drops. Salt particles from the ocean and dust particles swept into the atmosphere by wind will also serve as nuclei.

Problems

1. Why do you think that LaPorte, Indiana, and Queensland, Australia, experienced the weather changes described in "Air Contamination and Temperature," Section Seven?

TEACHER MATERIAL

NUCLEI

The process of drop-formation in clouds is not as simple as is suggested in the student text.

Although water commonly changes to its solid form, ice, at zero degrees Celsius, the small droplets of liquid water which make up clouds tend to remain liquid at well beneath this temperature (as low as $-39^{\circ}C$). Liquid water at temperatures beneath $0^{\circ}C$ is said to be "supercooled."

The cloud droplets are so small that air currents can hold them aloft, and hence they do not fall as rain. In order for rain to fall, the drops must grow to a larger size. Typical raindrops range in size from 200 microns (.008 inches) to 5 millimeters (1/5 inch).

The growth which results in precipitation occurs in one of two ways.

If ice particles are present in a cloud (in addition to supercooled water droplets) the ice particles may grow at the expense of the liquid droplets. That is, the droplets will evaporate and the ice crystals grow. When the ice particles become large enough they will fall. If temperatures are sub-freezing all the way to the ground it will snow. If the air below is sufficiently warm the falling ice particles will melt, and observers on the ground will experience rain.

Alternatively, if a large enough drop is formed (perhaps by collision of small droplets) it will fall. As it falls it will bump into more droplets and collect them into itself. Upon reaching a certain size the falling raindrop fragments into several small drops, each of which falls and collects more tiny droplets.

In the LaPorte, Indiana, area, impurities from the steel mills acted as nuclei and increased drop formation, thus producing weather unlike that of nearby areas not downwind from the steel mills.

In Queensland, Australia, the smoke particles act as nuclei and the rain falls near the cane fields. Downwind there are still plenty of nuclei, but insufficient humidity to form raindrops.

MORE ABOUT CLOUDS

As you have seen, the temperature at which water vapor begins to condense and form water droplets is called the dew point. When the upper air temperature drops below the dew point, and nuclei are present, water droplets can form to become a cloud. When this happens near ground level, the cloud is called a fog.

Years ago, people used to depend almost entirely upon the clouds for information about the coming weather. The type of cloud, as well as the direction it moves, gives some indication of approaching weather. Cloud information, in addition to other data, is still useful in predicting weather.

There are three main categories of clouds based on appearance.

Cirrus clouds are wispy or feathery. They are made up of ice crystals and are found very high in the sky, usually 20,000 feet or higher.

Stratus clouds are made up of thick, gray layers. They can be found near the ground (in which case, the clouds are called fog) to a little over a mile high. The droplets in stratus clouds are very fine. If rain falls from this type of cloud, it will be a drizzle.

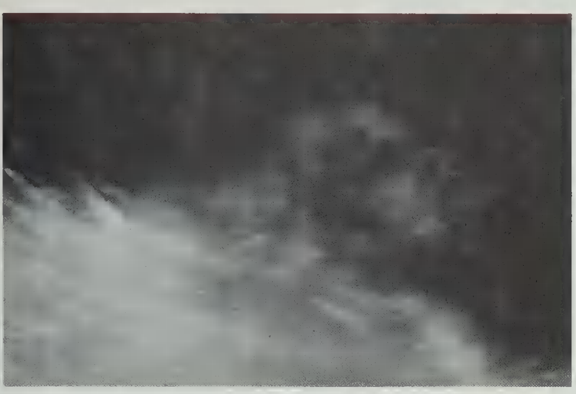
The familiar cotton-puff type of cloud often seen in a blue sky is called cumulus. These clouds have a flat base, indicating the lowest elevation at which condensation takes place. The cloud billows up vertically. Cumulus clouds sometimes cause heavy showers, which may be accompanied by lightning and thunder.

The three types of clouds can be further sub-divided into groups according to the height at which they are formed.

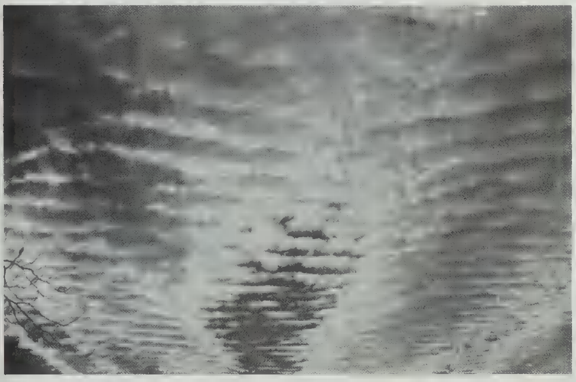
The following chart lists the cloud types.

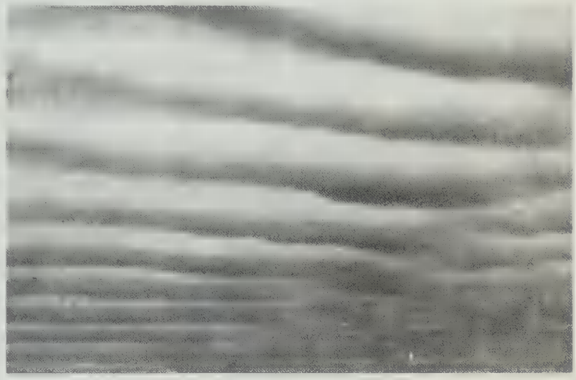
Cirrus	High Clouds (above 20,000 feet)
Cirrostratus	
Cirrocumulus	
Altocumulus	Middle Clouds (6,500-20,000 feet)
Altostratus	
Stratocumulus	Low Clouds (up to 6,500 feet)
Stratus	
Nimbostratus	
Cumulus	
Cumulonimbus	

Several of these cloud types are shown in Figure 8.8.


Cirrus


Cirrocumulus


Altocumulus


Stratocumulus


Cumulus


Cumulonimbus

Figure 8.8. Some Cloud Types.

Moisture which condenses into water droplets or ice crystals and falls from clouds is called precipitation. Some common forms of precipitation are rain, snow, sleet, and hail. The form depends largely upon the temperatures in the cloud and between the cloud and the ground. Liquid drops of precipitation are called rain. If water vapor in the cloud condenses directly into ice and falls to the ground without melting, the precipitation is called snow.

If the cloud temperature is warm enough to produce water droplets, but the air between the cloud and the ground is below freezing, the droplets will freeze on the way down. This form of precipitation is called sleet.

Hail is formed when strong vertical updrafts are present within a cloud. An ice particle from a higher level of the cloud falls, is caught in the updraft, coated with water and raised to a higher level where the added water freezes. The process is repeated till the updraft is no longer strong enough to lift the enlarged ice particle, which then falls as hail. Hail usually falls in the summer. Huge hailstones can be quite destructive.

Precipitation may fall on land or sea. The heat of the sun causes moisture on the surface to evaporate into water vapor. Moisture in the air will condense again, fall as precipitation and join with the surface water.

The change from water on the earth's surface to water vapor, from water vapor to water droplets, and from droplets to precipitation and evaporation again is called the water cycle.

FOR FURTHER ACTIVITY

1. Keep a record of the cloud types you see. Prepare a chart similar to Figure 8.10. In the "cloud cover" column place an estimate of the amount of the sky which is covered by the clouds. For example, if a little more than half the sky is covered, place .6 in the column. In the "cloud type or name" column write the name (such as "altocumulus") or description of the cloud (such as "high, lumpy"). Estimates of direction of motion and height may be entered in the corresponding columns. The amount of precipitation from the cloud can be measured with the rain gauge described in the next activity.

2. A rain gauge can be constructed from any straight-sided glass jar. Two or three millimeters of salad oil should be poured into the jar. This oil will float on top of accumulated rain and prevent its evaporation. See Figure 8.9. The rain gauge should be set out on a roof top or in a backyard where it will not be disturbed. The gauge should be checked every 24 hours. Accumulated water may be measured with a ruler. Hold the ruler outside the

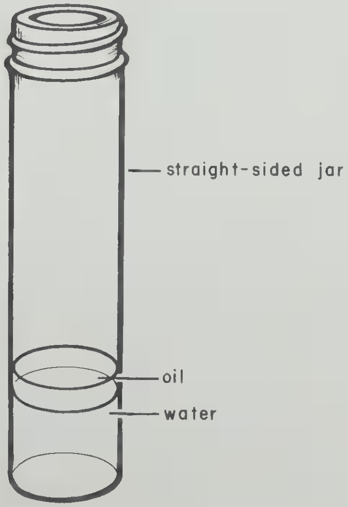


Figure 8.9. Rain Gauge.

jar, as dipping it into the gauge could affect the water level. Compare measurements made with the gauge to those given in newspapers or on television weather reports.

3. The depth of snow which falls on the ground can be measured directly with a ruler. Deep accumulations can be probed with a broom handle or similar stick which is then measured. All measurements should be made of snow which has fallen on level ground and has not drifted into unusually thick or thin deposits. The water content of snow can be measured by filling a straight-sided jar with snow. Do not pack the snow into the jar. The jar and sample should be brought into a warm room and allowed to melt without heating. Heating may cause evaporation or crack the jar. The depth of water formed by melting can be compared to the total height of the container. The fraction found in this way can be multiplied times the total snow depth to give the corresponding amount of rainfall.

DATE	TIME	CLOUD COVER	CLOUD TYPE OR NAME	DIRECTION OF MOVEMENT	CLOUD HEIGHT	PRECIPITATION TYPE	PRECIPITATION AMOUNT

Figure 8.10.

TEACHER MATERIAL

MORE ABOUT CLOUDS

The term "water cycle" is not introduced until the end of this reading section. However, an understanding of this recurring change--evaporation, condensation, precipitation, and back to evaporation--is one of the main aims of this passage.

Several cloud types are illustrated in the text. Memorization of their names is not important. More significant to the student is the fact that observations of the clouds will serve as one more bit of data that will help in understanding and forecasting the weather.

Clouds are classified in two ways: by cloud forms (cirrus, stratus, and cumulus) and by altitude (high, medium, and low).

The photographs can be compared with clouds in the sky for identification.

Students are asked to keep a chart (this can be done as long as interest lasts) of cloud types they see and the weather changes associated with them. Even though weather prediction involves much more than cloud observation, the student adds another dimension to his forecasting with this activity.

A further activity would involve identifying clouds in photographs (both in this book and in others) by comparison with the photographs given here.

In the course of discussions concerning precipitation students may ask about dew or frost. Dew and frost are not true forms of precipitation since they do not fall

from the clouds but form directly on surface objects. Water vapor near the ground can condense into either form. If the temperature is above freezing, dew forms. Frost appears when the temperature is below the freezing level.

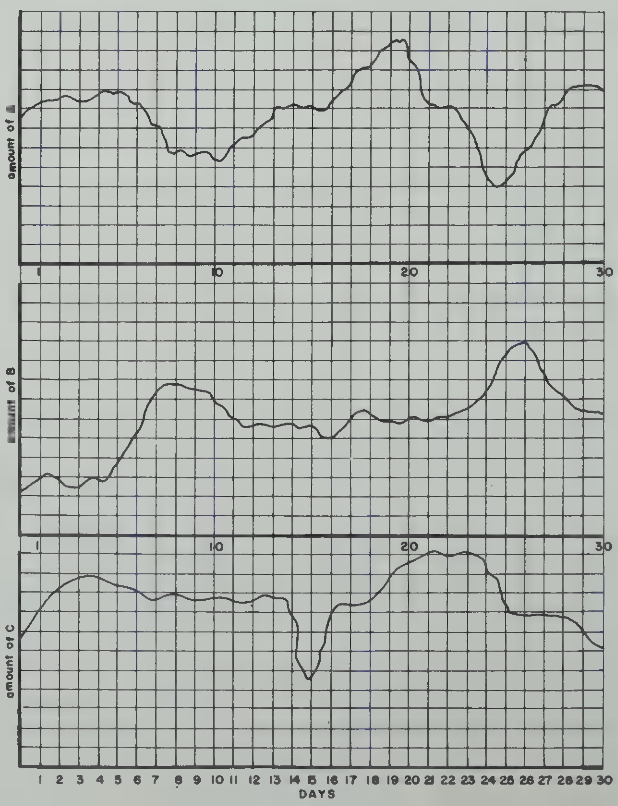
INVESTIGATION 8.9: Analyzing Records

By observing and measuring conditions in the atmosphere you have made a collection of records. The next step in learning about weather consists of looking for relationships between the different conditions which you have recorded. As an example, you may notice that particularly cold weather usually "goes along with" wind from a certain direction. This is the sort of relationship you should look for. "Analyzing" records refers to the process of discovering and stating relationships which are shown by the records.

Materials

Graphs of weather conditions

Figure 8.11.



Procedures

A. Compare graphs A and B of Figure 8.11. Notice that there are two "dips" in Graph A.

Interpretations

1. What, if anything, can you say about the amount of B at times when the amount of A is low?

2. What, if anything, can you say about the amount of B at times when the amount of A is unusually high?

Procedures (continued)

B. Compare Graph C to Graphs A and B.

Interpretations

3. What distinctive behavior, if any, is shown in the amount of C at times when amounts of A or B are unusually high or low?

4. Is there any distinctive behavior in the amount of C preceding or following changes in A or B?

Procedures (continued)

C. Compare your graphs of precipitation amounts and cloud cover. Be sure that the dates represented on the two are lined up vertically.

Interpretations

5. What relationship, if any, appears to exist between cloud cover and precipitation?

Procedures (continued)

D. Compare other graphs of weather data. For example, compare your temperature graph first to cloud cover and then to precipitation.

Interpretations

6. What relationships, if any, appear to exist?

ADDITIONAL ACTIVITIES

1. Continue to observe and record selected aspects of the weather. Decide whether relationships you have noticed in this investigation continue.

2. Attempt to predict weather using relationships you may have discovered in this investigation.

3. Prepare a set of graphs, in the same form as those of Figure 8.11, in which some relationship is hidden. Test other members of your class to see whether they can identify the relationship.

TEACHER MATERIAL

INVESTIGATION 8.9: Analyzing Records

The timing of this investigation is flexible. It is best scheduled after students have collected data which reflects one or two changes in weather, from warm to cold, from rainy to dry, etc. The investigation should not be postponed so long that students lose interest in maintaining records. It may be desirable to go through the investigation as soon as there is sufficient data to make one or more simple correlations. Making the analysis may assist in motivating students toward careful record keeping and encourage them to look for further relationships. It may also suggest additional data which should be recorded or changes in observational procedures. A few minutes of class time could then be devoted to repeating parts of the investigation whenever significant changes in weather are noted during the remainder of the school year.

Materials

A collection of newspaper weather reports and maps for the past week may be useful in substantiating the observations made by the class. Differences between "official" weather data and class data are to be expected. This should not be a point of discouragement for students since differences in location between the weather station and your school should result in differences.

Procedures

A. The two "dips" referred to are those occurring between days 7-10 and days 24-25. Procedures

related to Figure 8. are intended as examples of the types of relationships students should look for in their own records.

Interpretations

1. High "Amounts of B" correspond to low "Amounts of A."

2. There is no apparent relationship. Students might expect that the converse of Interpretation 1 should hold. Although there is a low in B corresponding to the initial high in A, there is no such low in B associated with the high reached by A on days 19-20.

<u>Procedures</u> (continued)

B. No comment.

Interpretations

3. There is no obvious relationship.

4. Rises in "Amount of C" precede the highs of B and the corresponding lows in A. A sharp decrease in C occurs a few days before the increase in A on days 19-20.

<u>Procedures</u> (continued)

C. No comment.

Interpretations

5. If precipitation has occurred during the period of observation, it should be noted that bars on the "Precipitation" graphs occur only during periods when "Cloud Cover"

graphs show readings in the higher part of the scale. This simple observation should be consistent with the students' experience. However, it may be noted that even a relatively high fraction of cloud cover does not necessarily result in precipitation. Try to have students notice that their graphs are, in a manner of speaking, making "statements" about the weather. The manner in which these "statements" are made, (markedly high reading, unusually low readings, abrupt changes in slope, etc.) should be looked for in other graphs.

<u>Procedures</u> (continued)

D. No comment.

Interpretations

6. Student responses will vary. Although it is difficult to make generalizations about weather, some typical correlations might be:

Barometric pressure drops before and during periods of cloudy weather and rises with the approach of clear weather.

Wind shifts (often to the south) occur before the arrival of precipitation.

In winter, air temperatures drop during periods of clear weather.

Precipitation is associated with lower cloud types and not with cirrus.

ADDITIONAL ACTIVITIES

1.-3. No comment.

Data collection and analysis of records are two essential steps in the progress of science. Each calls for a different type of skill. You may find that some students enjoy taking measurements and preparing graphs. Others may be better at detecting subtle relationships between graphs but have difficulty in handling equipment. The point is, cooperation is essential among professional scientists. You may wish to mention this to your class.

A talent for seeing relationships is close to the heart of science, but so is a cautious approach toward making generalizations which are based on only a few observations. The ability to make the broadest possible generalization which is justified by the available evidence is gained only through practice.

Section Nine:

Observing the Landscape

PREVIEW

Section Nine provides students with an introduction to geology. The first two investigations show how landforms may be interpreted to give evidence for change. The forms studied, terraces along shorelines, indicate that in some places the land has been rising.

A second example of a way in which the land may be built up is cited in a short reading selection on volcanoes. Following the text relating to volcanoes, three investigations--dealing with crystals, minerals, and volcanic rocks--lead toward an understanding of the relationship between rock textures and the conditions under which igneous rocks have formed.

Another process by which the earth's surface may be built up, sedimentation, is approached through a student activity and interpretation of photographs. This is followed by a laboratory investigation of sedimentary rocks.

Other characteristics of rivers are then introduced. Rivers are seen to form a bridge between processes which build up the land and those which tend to level it.

A second earth-leveling process, soil creep, is introduced through an investigation in which students attempt to recognize and define a problem.

Deformation and its effects on topography are discussed briefly, and then the rock types attendant upon deformation--plutonic and metamorphic--are introduced in laboratory investigations.

The section closes with a consideration of the effects of ice as a geologic agent.

Section Nine:

Observing the Landscape

Waves rush on a sandy beach. Misty rain falls on a grassy slope. A rock clatters down a mountain side. The shape of the land has been changed.

Every wind that blows, each snowflake settling on a wintry field does its part. Commonplace events, ordinary stones, tell of distant mountains and bygone glaciers. How can the clues be read? What can the landscape suggest about happenings of the past and of changes that are going on now? What is in the future?

These are the questions you will now consider.

TEACHER MATERIAL

DOES THE EARTH'S SURFACE CHANGE?

It is likely that students will already know that the landscape changes under the influence of time. Such words as "erosion," "weathering," and "volcano," with their implications of change, enter the vocabulary early. As in previous sections of the course, however, students should be asked to set aside temporarily what they may know about the landscape and its development in order to re-establish their knowledge on the basis of evidence presented.

FIELD TRIPS

It is intended that students become aware of the types of observations which are useful to geologists. Students should be encouraged to make their own observations and speculate on the implications of the land forms around them. The value of field trips in encouraging such observation and interpretation cannot be overemphasized. Each geographic area has its own features and its own stories to tell. Through field trips students come to see that "geology" is not something which occurs in far-off corners of the world, but something which surrounds each one of us wherever he may be. In this connection, the most valuable field trips are those in which the <u>least</u> travel is involved. Besides being more difficult to arrange, trips to distant locales tend to reinforce the notion that geology is found only in books, movies or far distant places.

Teachers whose schools are located in cities will necessarily build field trips around different aspects of geology than those in rural settings. Questions such as

the following might be considered: What (geological) factors caused a city to be built here? Is the land level? Why is it level? Is there a river nearby? Has the course of the river been changed by man? Or: Why was this city able to develop where there is no river? What are the buildings made of? Where do the brick, stone and cement come from? What can be seen in excavations for tunnels and foundations?

Teachers whose schools are in less developed areas will be able to direct students' attention to features which have been less altered by man: What is the drainage pattern here? Why do the hills or plains around us exist? What can we look for to see whether the landscape has changed, is changing, or will change?

If an organized class field trip is impossible, students can be asked to make observations of geologic interest around their homes and en route to school and report to the class.

The timing of a geology field trip is a matter of individual preference. Some teachers will wish to schedule a field trip early in the section in order to stimulate interest and raise questions. Others will wish to hold the trips after the students have been made aware of the sorts of geologic evidence to look for. In either case, a field trip should be preceded by a briefing session and followed by class time in which observations can be discussed.

If for some reason field trips are completely impractical, thought should be given to preparing a slide show of the terrain in the vicinity of the school. A class discussion may then be built around the slide show.

Colleges and universities, as well as many public libraries, usually maintain geology libraries which will contain specific information on the local geologic setting. Such libraries are invaluable to the teacher who wishes to lead field trips but does not have a strong background in geology.

INVESTIGATION 9.1: Water Level Changes

The first of the possible changes in landscape you will consider is that of sea level. In order to decide whether sea level has changed you should look at the landscape for evidence of change. But what sort of evidence would be left of such a change? In this investigation you will observe the effects of water level changes on a miniature shore line.

Materials (per team)

Ice cube tray
Sand
Water
Sponge

<u>Procedures</u>

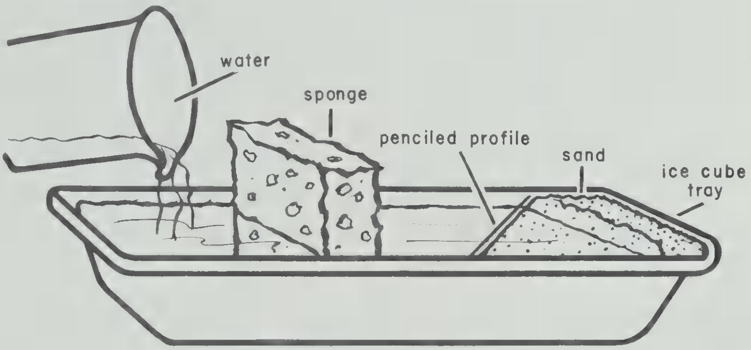
A. At one end of the ice cube tray form a smooth, sloping pile of sand. The sand should slope down from the top of the tray at about 1cm in 2. That is, if the sand is piled 3cm high at its higher end, the lower end of the slope should be about 6cm out from the end of the tray.

B. Use a pencil to mark the profile (the outline) of the sand on the side of the tray. Be careful not to disturb the sand while doing this.

C. Hold a moistened sponge across the tray as shown in Figure 9.1. The sponge will prevent water currents from disturbing the sand while you fill the tray. Pour water slowly into the tray until the surface of the water is about 1cm from the

top of the tray. Once water has been added to the tray, do not remove the sponge until instructed to do so. Otherwise the level of the water might be changed. Make a short, horizontal pencil mark to indicate water level on the side of the tray. This line should intersect the profile line.

Figure 9.1. Filling Tray.



D. Keep the lower end of the sponge in contact with the bottom of the tray. Do not allow it to slide across the bottom of the tray. Move the top of the sponge back and forth to produce small waves. The waves should be about .5cm high and should be made at a rate of about 2 per second. Continue to make waves for several minutes, watching all the time for changes in the profile of the sand.

Interpretations

1. Describe the change in profile of the sand.

2. At what level did most of the change occur?

3. Why do you think there was little change below this level?

4. Could the waves indirectly cause changes above the highest level they reached? Explain.

<u>Procedures</u> (continued)

E. Remove the sponge from the tray and squeeze it dry. Carefully dip and squeeze the sponge until the water, with the sponge in it, is about 1cm lower than originally. Use a pencil to mark the new sand profile and water level on the side of the tray.

Interpretations

5. Make a sketch in your notebook to show what you think the profile will look like after a new series of waves has been made.

<u>Procedures</u> (continued)

F. Repeat Procedure D.

Interpretations

6. Was your prediction (Interpretation 5) correct?

TEACHER MATERIAL

INVESTIGATION 9.1: Water Level Changes

Materials

Baking pans or other rectangular containers may be used in place of the ice cube trays.

Sponges are specified as wave generators because they absorb reflected waves and minimize random water motion.

A bucket or other large container, partly full of water, should be available to allow for disposal and recovery of used sand. If fine beach sand is not available otherwise, it can be purchased at building supply or aquarium supply houses. Individual grains of approximately .5mm work well. Where sand is not available, cornmeal has proved satisfactory.

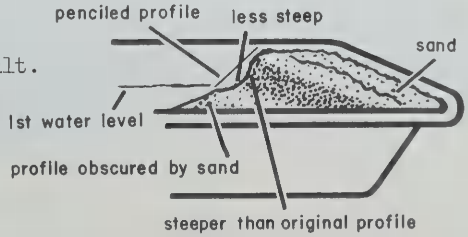
Procedures

A.-D. No comment.

Interpretations

1. Responses will vary. A typical result of Procedures A-D is shown in Figure T-9.1. Encourage students to use sketches in describing profiles.

Figure T-9.1. Typical Result.



2. Most change occurs at or near water level.

3. The waves occur at or near the surface of the water and have progressively less effect at depth.

4. Yes, waves can have indirect effects above the highest level they reach. They may undercut the sand, resulting in the collapse of a cliff.

Procedures (continued)

E. No comment.

Interpretations

5. Student responses will vary.

Procedures (continued)

F. Students should be instructed to rinse their trays by dipping them into the large container. Sand should not be washed down the sinks.

Interpretations

6. Student responses will vary. A typical result of Procedures A-E is shown in Figure T-9.2. The originally smooth slope is now broken by two "cliffs" and two "terraces." This terminology is introduced to the students in the next investigation.

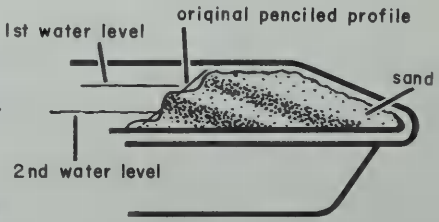


Figure T-9.2. Second Terrace Formed.

INVESTIGATION 9.2: Ancient Shore Lines

You now know the effect of waves on a miniature shore line. Do the waves in oceans and large lakes have similar effects upon their shore lines?

Materials

None

Procedures

A. Examine Figure 9.2. The level land in the central part of the photograph is known as a "terrace." The steep ground between the terrace and the ocean is referred to as a "cliff." Look for similarities between the landscape in this photograph and the profile produced in Investigation 9.1.

Figure 9.2. Coastline.

Interpretations

1. What do you think was the location of sea level at the time the large terrace in the central part of the photograph was formed?

2. Why do you think your answer to Interpretation 1 is correct?

3. Where were the waves striking the shore at the time this terrace was being formed?

4. Do you see evidence of a new terrace being formed? If so, where is it being formed?

5. In what way does the cliff give evidence that waves are having an indirect effect on the landscape at a level higher than they can reach directly?

6. What change in sea level has apparently occurred between the time of formation of the central terrace and the present?

7. What evidence do you see of other terraces at higher elevations than the central terrace?

8. Why do you think the highest terraces and cliffs are less distinct than the central ones?

If you think about it, it should be plain that a rise in sea level (while the land stays at the same height) would have the same effect on a shore line as a drop in the level of the land (while the sea stayed at the same level). Are there still other changes which would cause an apparent rise in sea level?

Procedures (continued)

B. Copy Figure 9.3 in your notebook.

Figure 9.3. Changes Causing an Apparent Rise in Sea Level

	Actual Height of Sea	Actual Height of Land
1	rises	stays same
2		
3		
4	rises rapidly	rises slowly
5		

Interpretations

9. Two of the possible five changes which would cause an apparent rise in sea level have been listed. Fill in the table to indicate what you think the other three would be.

Procedures (continued)

C. Copy Figure 9.4 in your notebook.

Figure 9.4. Changes Causing an Apparent Drop in Sea Level

	Actual Height of Sea	Actual Height of Land
1		
2	drops	rises
3		
4		
5	rises slowly	rises rapidly

Interpretations

10. Two of the possible five changes which would cause an apparent drop in sea level have been listed. Fill in the table to indicate what you think the other three would be.

11. Do you think that changes in sea level in the area of the photograph (Figure 9.2) have occurred steadily or as a series of abrupt changes followed by periods of no change?

<u>Procedures</u> (continued)

D. Design and carry out an experiment to test your ideas using laboratory equipment. Record your procedures and results in your notebook.

E. Examine Figure 9.5, a photograph taken in Utah.

Figure 9.5. Possible Shoreline.

Interpretations

12. Near the center and left of the photograph is an almost straight feature. In what way, if any, does the feature suggest a former shore line?

13. What makes it seem unlikely that this would be a former shore line?

14. What can you think of, besides wave action, that might have caused this feature?

15. Suppose you were able to investigate the area of Figure 9.5 on foot. What sorts of evidence, if found, would support the idea that this might once have been a shore line?

TEACHER MATERIAL

INVESTIGATION 9.2: Ancient Shore Lines

Materials

Though no materials are required, it is desirable to supplement the photographs appearing in this book with others.

Procedures

A. No comment.

Interpretations

1. At the time the large terrace was formed, sea level was probably at (or a few feet above) the level of the terrace.

2. In the preceding investigation it was found that a flat "terrace" was formed slightly below the level of the water. The same process may have occurred in the area of the photograph.

3. The waves would have been striking near the base of the cliff above the terrace.

4. Yes. This terrace extends out to sea for some distance from the present beach. The breaking waves in this zone imply that the water beneath them is shallow.

5. Although it is not possible to tell from the photograph just how high the highest waves reach, it seems unlikely that they would reach all the way up the

cliff. Thus the cliff is probably a result of undercutting by the waves followed by collapse.

6. Sea level has apparently dropped.

7. The remains of older terraces may be seen above and behind the central terrace. Though not as distinct as the main terrace, they show the characteristic level areas separated by steeper zones.

8. The higher terraces have been more eroded than the central terrace. This is evidence that they are older.

<u>Procedures</u> (continued)

B. The next part of the investigation is concerned with apparent changes in sea level. Since most heights are measured relative to sea level, it may be confusing to students to think about changes in the reference point. By "actual height" is meant the distance from the center of the earth.

Interpretations

9. See Figure T-9.3.

Figure T-9.3. Changes Causing an Apparent Rise in Sea Level

	Actual Height of Sea	Actual Height of Land
1	rises	stays same
2	rises	drops
3	drops slowly	drops rapidly
4	rises rapidly	rises slowly
5	stays the same	drops

Procedures (continued)

C. No comment.

Interpretations

10. See Figure T-9.4.

Figure T-9.4. Changes Causing an Apparent Drop in Sea Level

	Actual Height of Sea	Actual Height of Land
1	drops	stays the same
2	drops	rises
3	drops rapidly	drops slowly
4	stays the same	rises
5	rises slowly	rises rapidly

11. The changes in sea level relative to the land have occurred as a series of abrupt changes. Each change was followed by a long, stable period, during which there was sufficient time for a terrace to develop.

Procedures (continued)

D. One way in which the test could be conducted would involve the apparatus of Investigation 9.1. As one student produced the waves, as in Procedure D of that investigation, a second student could be slowly but steadily removing water from the tray. Under such conditions no distinct terraces would form.

Reference to the results of Investigation 9.1 will show that distinct terraces <u>are</u> formed when periods of stability intervene between periods of rapid change.

E. No comment.

Interpretations

12. The very straightness of the feature resembles that of shore lines in Investigation 9.1 and in Figure 9.2 of this investigation. The steep part of the feature resembles a cliff. Level areas above and below the cliff resemble terraces.

13. There seems to be no nearby ocean to have formed the cliff and terraces.

14. Student answers will vary. Encourage students to suggest as many alternatives as possible. The feature might be man-made. It might be composed of a hard rock which has resisted erosion.

15. Deposits of beach sand or of fossils such as clams would support the idea that this is a shore line feature. The bottoms of large basins in this area frequently contain deposits of salts left by evaporating water. Alternatively, close inspection might show evidence supporting one of the other possibilities: a harder rock than in surrounding areas, evidence of human activity, rocks crushed and polished by fault activity, etc.

At this point no definite statement should be made concerning the origin of the feature in Figure 9.5. It will be considered again later.

VOLCANOES

At two minutes before eight on the morning of May 8, 1902, Leon Compére-Leandre sat on the doorstep of his home. It was a lovely morning in Saint-Pierre, Martinique, an island in the Caribbean. A change in the wind had made the air more clear than it had been for a number of days. At this time Leon Compére-Leandre had little in common with Auguste Ciparis. Leon was a shoemaker, Auguste a stevedore. Leon was a free man, Auguste a convict in the city prison. In all likelihood the men had never met. They were simply two of the people in a city of 30,000. Within minutes they shared a terrible bond, for they were the only two people still alive in Saint-Pierre.

The poor visibility of past days had been the result of dust and ash rising from nearby Mt. Pelée and raining down on its surroundings. Mt. Pelée, a volcano, had shown increasing signs of activity for the past year, mainly in the form of eruptions of ash. On the second of May there had been a spectacular display of lightning in the ash cloud over the volcano. Then between 7:59 and 8:02 on May 8 there were four great explosions. The side of Mt. Pelee burst open and a cloud of glowing gases swept down on Saint-Pierre at over 100 miles per hour.

In June of 1912 an eruption in the neighborhood of Mt. Katmai, Alaska, could be heard at a distance of 900 miles. For many miles around volcanic ash was so thick in the air that people could not tell night from day. An officer on the U.S. Coast Guard Cutter Manning reported that the light of a lantern could not be seen at arm's length. Dust remaining in the upper atmosphere after this eruption reduced the earth's incoming solar energy by an estimated 10% and lowered average temperatures throughout the Northern Hemisphere by 1°C for the better part of two years.

Figure 9.6. Surtsey.

During November of 1963 a series of volcanic eruptions resulted in the appearance of Surtsey, a new island, off the coast of Iceland. See Figure 9.6.

Without doubt, volcanoes are some of the most awesome things in nature. Behind our appreciation of the serene beauty of Fujiyama (Figure 9.7) in Japan or Popocateptl in Mexico lies a fear that one of these volcanoes may without warning devastate the land about it.

Figure 9.7. Mount Fuji.

In contrast to the violence with which mountains such as Pelee have burst out is the relative calm with which the Hawaiian volcanoes erupt. Tourists and scientists alike can observe their activity from relatively short distances, secure in the knowledge that the activity will consist of flows of molten rock rather than violent explosions. Why the difference? The dark lavas of volcanoes which rise from the deep ocean floor seem to be much more fluid than the lavas of volcanoes which occur on land or on islands which are close to continents, like Martinique. See Figure 9.8. The stickier continental lavas tend to block volcanic openings resulting in build-ups of enormous pressure.

Figure 9.8. Kilauea.

Since lava comes from deep within the earth, this difference between types of lavas may reflect fundamental differences in the types of rock composing continents and underlying the oceans.

Problems

1. Compare early accounts of the 1912 eruption of Katmai with recent interpretations of the eruption. What caused the change in scientific thought? Are such changes unusual?

2. How might volcanic activity have caused the ice age mentioned in Section Seven? What geologic evidence could you look for to show whether this actually happened?

TEACHER
MATERIAL

VOLCANOES

Problems

1. Information on Katmai has not been well publicized and may be difficult to obtain. Following the events mentioned in the text, it was noticed that a new crater 3 1/2 miles x 2 1/2 miles x 1/2 mile deep had formed on Katmai. It was assumed that the material missing from this depression had been blasted into the air to form the ash mentioned. More recent observations, particularly by Dr. Garniss Curtis, show that the actual eruption was from Novarupta, some five miles away. The crater mentioned formed as a result of collapse when lava, presumably under the crater, moved by underground conduits toward the eruption site.

2. Widespread volcanic activity at some past time may have placed enough dust in the air to lower temperatures enough to cause the onset of an ice age. If ice samples could be obtained from deep within ice-caps they might show volcanic dust which had fallen from the atmosphere. Students may think of other mechanisms and of other tests.

Students who wish to read about other volcanoes may be directed to look for references to Krakatoa. Even those students with limited supplies of reference materials should be able to find information concerning this volcano. The eruption of the mountain produced the loudest sound known, heard 3,000 miles away. A great tsunami, or sea wave, 135 feet high resulted from the eruption and caused the

deaths of 36,000 people. Material was ejected to heights of 50 miles, and atmospheric dust from the event produced colorful sunsets around the world for years thereafter.

INVESTIGATION 9.3: A Common Form of Matter

Many of the things you see and handle in your daily life are composed of crystals. Such substances are not always easy to recognize. In this investigation you will deal with minerals, naturally occurring crystalline substances, and consider a model for their properties.

Materials

Mica, quartz, feldspar, calcite
Ice cube tray
Detergent
Soda straws
Water
Transparent tape
Straight pin

Procedures

A. Examine and compare the four mineral specimens.

Interpretations

1. What statement can you make about flat surfaces on the specimens?

2. What statement can you make about straight edges on the specimens?

3. Which minerals, if any, show distinct angles between their flat surfaces?

4. Which minerals, if any, have a tendency to reflect light especially well?

5. Predict the way in which you think each specimen might tend to break.

Procedures (continued)

B. Use your fingernail to split the mica.

Interpretations

6. Is there one direction in which mica will split particularly well?

7. Are sheets of mica flexible or brittle?

Procedures (continued)

C. Under the supervision of your teacher tap each of the specimens with a hammer. Observe anything unusual about the way in which the specimens break.

Interpretations

8. Describe the way in which calcite breaks.

9. Describe the way in which quartz breaks.

10. Describe the way in which feldspar breaks.

11. Describe the way in which mica breaks.

12. What structure can you think of which would explain the way in which the minerals break?

Procedures (continued)

D. Fill the tray with water to within 1cm of the top. Add a few drops of detergent to the water.

E. Place tape over one end of a straw as shown in Figure 9.6. Use the pin to make a hole in the tape just large enough to let air escape when you blow gently into the other end of the straw.

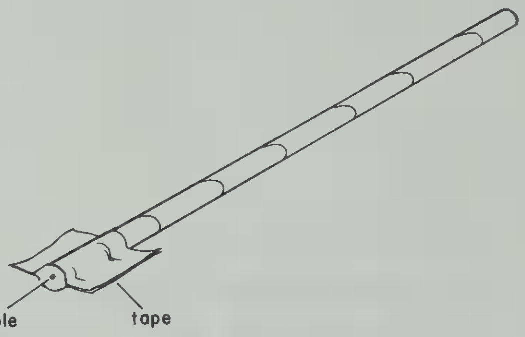


Figure 9.9.

F. Gently stir the water with the taped end of the straw in order to mix the detergent. Any bubbles which form should be pushed to the side of the tray. Hold the taped end of the straw a short distance beneath the surface of the water. Blow gently and steadily into the straw. Practice doing this until you can produce "rafts" composed of small (about 2mm) bubbles. Move the taped end of the straw while blowing so that each raft is only one layer of bubbles thick.

Interpretations

13. Describe any order or pattern you see within the rafts of bubbles.

<u>Procedures</u> (continued)

G. Use the straw to separate a raft into two parts. Make a sketch of one of the broken rafts in your notebook.

Interpretations

14. Do the bubble rafts tend to break along straight lines?

15. Describe a model for the structure of crystals based on your observations of bubbles.

TEACHER MATERIAL

INVESTIGATION 9.3: A Common Form of Matter

Metals are generally crystalline, though the crystal structure is not apparent. Galvanized iron objects, old brass doorknobs and fractures in iron sometimes show crystals. Glasses and plastics are not crystalline.

Materials

Liquid dishwashing detergent is convenient and effective.

Blow tubes may also be made by heating glass tubing over a bunsen burner and then pulling the ends apart. The tubing is then snapped at its thinnest point, producing two tubes. Be sure to fire-polish the ends of the tubes that students will blow into. These tubes should produce finer, more consistent bubbles than do straws.

A hammer and a hard, flat surface (such as a piece of iron) should be available in the classroom.

A knife or single-edge razor blade may be useful in demonstrating the properties of mica.

Procedures

A. No comment.

Interpretations

1. Quartz tends to occur in six-sided crystals with pointed, pyramidal ends. Mica occurs in "books" which are bounded by a pair of flat, parallel faces. Feldspar

crystals are blocky in shape. Two pairs of faces are parallel; the third pair is less regular. Calcite crystals are more regular than those of feldspar, being bounded by three pairs of parallel faces.

2. Some crystals of mica may show six edges; others will not. Quartz will have straight edges between crystal faces but irregular lines along fractures. Feldspar and calcite specimens have straight edges between the flat faces mentioned in Interpretation 1.

3. In some specimens, at least, quartz, feldspar and calcite exhibit distinct angles.

4. Mica has highly reflective surfaces. Calcite and quartz are generally somewhat less lustrous. Feldspar is quite lustrous on its flat surfaces, less so on end surfaces.

5. Student responses will vary.

<u>Procedures</u> (continued)

B. Students should be encouraged to split mica repeatedly to obtain the thinnest sheets possible. You may wish to demonstrate, using a razor blade, that mica can be split into extremely thin sheets.

Interpretations

6. Mica will split quite nicely at any point along the direction of the plane of its parallel faces. It is said to have "one direction of cleavage."

7. Thin sheets of mica are quite flexible.

Procedures (continued)

C. It is best to cup one hand around the sample in order to safeguard against flying fragments.

Interpretations

8. Calcite splits along three sets of parallel planes each of which is roughly at right angles to the other two directions. It may be described as having three directions of cleavage.

9. Use caution in hitting quartz. The mineral is both hard and tough, and considerable force may be needed to break a crystal. Although quartz is described as having one poor direction of cleavage (perpendicular to the six sides of its prism), this cleavage is not distinct. Each quartz crystal has a maximum of one set of regular faces. If these faces are absent or are destroyed other regular surfaces will not be formed. Be sure to point out to the students the distinction between "crystal faces" which mark the limits to which a crystal has grown and "cleavage surfaces" which are exposed as a result of breaking a crystal.

10. Feldspar cleaves regularly along two directions and breaks in irregular fashion in the third direction.

11. Mica can be crushed by a hammer blow. Its cleavage is best demonstrated by splitting, as outlined in Procedure B.

12. Student responses will vary.

Procedures (continued)

D.-F. No comment.

Interpretations

13. Students should note that bubbles tend to align themselves into regular arrays with more or less straight edges. "Surface tension," the attraction between water molecules, pulls bubbles into clusters and holds them there. This effect is analagous to the electrical forces which align the ions in crystal lattices.

Procedures (continued)

G. See Figure T-9.5.

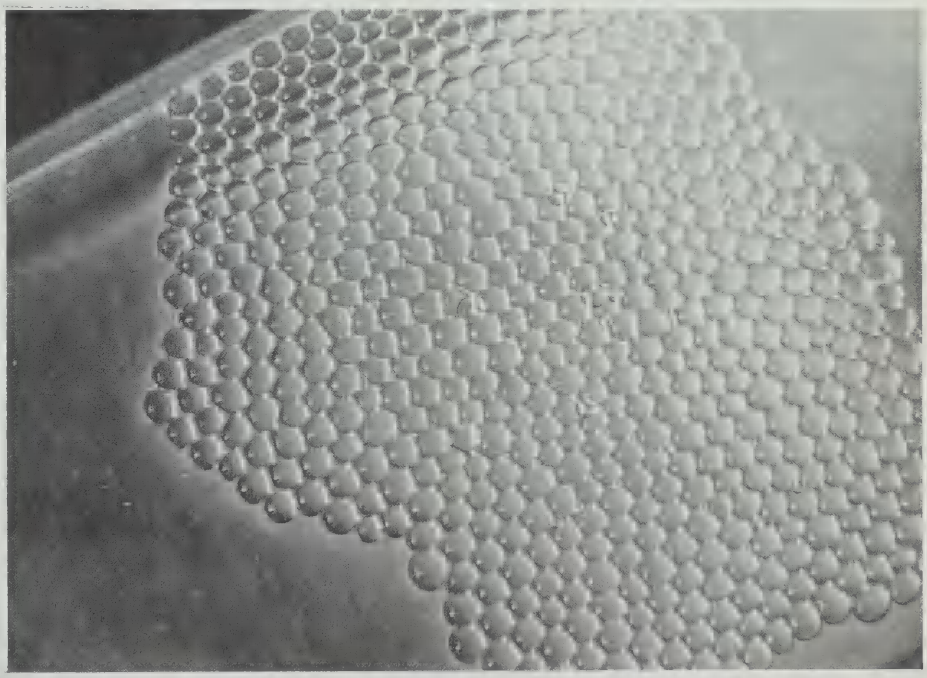


Figure T-9.5. Bubble Raft.

Interpretations

14. The rafts do tend to break along straight lines. This is analagous to the parting of crystals along cleavage planes.

15. The properties of crystals provide an excellent line of reasoning leading to an atomic model for matter. The smooth crystal faces and cleavage planes of crystals suggest that the particles of which they may be composed are extremely small. The idea of non-symmetrical forces binding together the units within crystals is consistent with preferred directions of cleavage in crystals. However, the point of the investigation is more to acquaint students with cleavage than to develop a model for the structure of matter.

The property of minerals which is most obvious at a first inspection is color. Color can be misleading. The color of quartz may range from clear to milky and from rose, through amethyst to smoky. Regardless of color variations, quartz follows its hexagonal crystal habit with poor cleavage. This is a consistent distinguishing characteristic. Students who learn to recognize cleavage will have acquired a valuable tool for mineral identification.

INVESTIGATION 9.4: The Textures of Solids

By examining solids it is often possible to obtain clues about the conditions under which they were formed. In this investigation you will consider the effect of allowing a melted substance to cool at different rates.

Materials (per team)

Microscope slide (2)
Magnifying lens
Salol
Hot plate or alcohol burner
Ice cube

CAUTION: Although the salol is not especially poisonous, all chemical substances should be treated with caution. Wash your hands after completing this investigation.

Procedures

A. Put a small amount of salol near one end of each of the two microscope slides. Enough to form a spot .5cm to 1cm in diameter is sufficient.

B. Warm one slide gently until the salol is almost completely melted. When only a few bits of unmelted salol are still present, place the slide on the table to cool slowly. Examine the salol after it has hardened.

C. Heat the second slide as in Procedure B. When the salol is almost completely melted, cool the slide quickly by rubbing it on an ice cube. Compare the quickly and slowly cooled specimens.

Interpretations

1. Describe similarities and differences in appearance of the two specimens.

2. If crystals in a rock were formed by quick cooling, would you expect them to be large or small?

3. Under what conditions would you expect melted rock to cool more rapidly, in the air or deep underground?

PROBLEMS

1. The term "crystal" has not been defined in the text. What is there about the appearance of crystals that allows you to recognize them for what they are?

FOR FURTHER ACTIVITY

1. Remelt one of the specimens of salol. Continue to warm it until all solid material has completely melted. Observe the specimen as it cools slowly on the table. If the salol has not hardened after a minute or so, drop a small bit of solid salol into the melted material. How do you account for your observations?

2. Prepare a solution by dissolving magnesium sulfate ("epsom salt") in water. Epsom salt may be obtained at most drug stores. Allow samples of the solution to evaporate at different rates by placing containers in warmer and cooler places. Describe any differences in crystals which form.

INVESTIGATION 9.4: The Textures of Solids

The purpose of this investigation is to show students that small crystals form when a melt cools rapidly and larger crystals form when a similar melt cools more slowly. By analogy it can be concluded that small crystals in igneous rocks reflect rapid formation during quick cooling near the surface of the earth. Larger crystals represent slower cooling which has occurred at greater depths.

Materials

Salol (phenyl salicylate) can be obtained from most chemical supply houses.

Wood splints or a spatula should be available to students for measuring out the salol.

Slides on which the salol has hardened can be kept for re-use by other classes.

Procedures

A. No comment.

B. If bunsen burners or other high-heat sources must be used, tell students to move the slide in and out of the flame to avoid cracking the glass or over-heating the salol. Kitchen matches or candles are also sufficiently hot to melt the salol.

C. No comment.

Interpretations

1. Crystals formed on the two slides will be similar in color, luster, transparency and form, but those formed slowly will be larger than the crystals on the quickly cooled slide.

2. Crystals formed when rocks cool quickly are small. If the rock cools very rapidly, there may be no time for orderly growth, and the rock will have a glassy texture.

3. Rocks which cool near the surface can lose heat to the air rapidly. Those which cool at depth cannot lose heat as rapidly. Therefore they cool slowly and will likely contain large crystals. Another factor, not mentioned in the student text, which favors growth of large crystals in igneous rocks is a high water content in the molten material.

PROBLEMS

1. By definition, crystals are substances which are composed of orderly arrangements of atoms. A crystal of quartz, for example, consists of an array of silicon and oxygen atoms. Although there is a definite ratio of silicon to oxygen (1:2) there is no definite number of SiO_2 units within a single crystal. Thus single crystals may range in size from microscopically small to several meters in length. Not all crystalline substances can be recognized by inspection. A substance is likely to be crystalline if:

straight edges and flat faces are present;
the surface is highly reflective;
distinct angles are found between flat sides;
fractures in the material occur along flat surfaces.

FOR FURTHER ACTIVITY

1. Even if the melt cools to below its "freezing" temperature it will not crystallize if no nuclei are present. It is for this reason that students are told, in Procedure B, to heat the salol only until "a few bits of unmelted salol are still present." The unmelted bits serve as nuclei for crystal growth in the cooling melt.

In this procedure the salol is heated until unmelted potential nuclei are all gone. The cooling material will probably not crystallize until a few nuclei, in the form of bits of solid salol, are added. Rapid growth away from these nuclei will then be observed. Students may recognize a parallel between these nuclei and those mentioned in connection with water-droplet formation in Section Eight.

2. Students should notice that slowly grown crystals attain larger sizes than do those which are grown more rapidly. Thus there is a similarity between crystal growth from melts and from solutions.

INVESTIGATION 9.5: Volcanic Rocks

Rocks can be grouped or classified in many ways. In order to classify them you must look for similarities and differences. When you look at rocks you may observe that some are larger than others. However, a small piece broken from a larger rock is still the same kind of rock. You might group rocks according to crystal size or density or hardness. After you examine the rocks, choose your own basis for classification. You will also have an opportunity to decide which substances are contained in different rocks.

Materials (per team)

Volcanic rock set
Mineral set

Procedures

A. Develop a classification system for the volcanic rocks in your set. (Each member of your team may have a different system.) Examine another set of volcanic rocks to find whether your system can be used for any similar set of rocks.

B. Recall the results of Investigation 9.4, The Textures of Solids. Examine the textures of volcanic rocks.

Interpretations

1. Do you think the rocks in your sample cooled rapidly or slowly? Give reasons for your answers.

Procedures (continued)

C. Use a labeled set of volcanic rocks to find the name of each rock in your set.

Interpretations

2. For each rock in your set write a thorough description including texture, color, how it reflects light, and any other properties you observe.

Procedures (continued)

D. Use a labeled set of minerals to find the name of each mineral in your set. Divide the set into two groups: light colored minerals and dark colored minerals.

Interpretations

3. Record the results of Procedure D in your notebook.

Procedures (continued)

E. On the basis of color, decide which minerals you think are in each of the volcanic rocks.

Interpretations

4. Record the results of Procedure E in your notebook.

5. What evidence would indicate that gases were present in rocks as they were formed?

6. Which rocks (if any) in your set were formed from material containing gas?

TEACHER MATERIAL

INVESTIGATION 9.5: Volcanic Rocks

Materials

Volcanic rock set: Each set should contain basalt, obsidian, rhyolite, pumice and scoria.

Mineral set: Each set should contain quartz, light and dark mica (muscovite and biotite), feldspar, olivine, hornblende and garnet.

There should be one or more labeled sets of each kind in the room in addition to the unlabeled sets for each team. If possible, there should be some variety in sizes and shapes of specimens.

Procedures

A. Some possible classification schemes are:

(Color)
light--rhyolite, pumice
dark--basalt, scoria, obsidian

(Presence or absence of bubbles)
bubbles--pumice, scoria
no bubbles--basalt, obsidian, rhyolite

(Reflection of light)
shiny (glassy)--obsidian, pumice
dull--basalt, scoria, rhyolite

Students should be encouraged to develop their own basis for classification, but to avoid systems based on the size or outline of the rocks in their set.

B. No comment.

Interpretations

1. The rocks probably cooled rapidly because crystals, if present, are too small to be seen. If this is not apparent to students do not press the point. After they have seen the more coarsely crystalline rocks of Investigation 9.10 they will have a better idea of what is meant by "large" and "small" crystals.

<u>Procedures</u> (continued)

C. If only one labeled set is available, the teams could take turns using it. It would be better to have more than one labeled set so that samples could show some of the normal variation in size, shape and color for each type.

Interpretations

2. Sample answer:

Rock	Texture	Color	Light Reflection	Other
Basalt	like very fine sandpaper	dark	dull	
Obsidian	smooth	dark	shiny	Curved lines on broken surfaces Light passes through thin edges
Pumice	filled with small bubbles	grey	shiny	Very light weight for its size
Scoria	many bubbles	dark	dull	
Rhyolite	like fine sandpaper	light	dull	

Procedures (continued)

D. Same comment as for Procedure C.

Interpretations

3. Grouping by color:

Light colored minerals	Dark colored minerals
Quartz	Olivine
Feldspar	Hornblende
Mica (Muscovite)	Garnet
	Mica (Biotite)

Procedures (continued)

E. Encourage students to make intelligent guesses based on their observations. If they expect to be told the "right" answer, they may not want to commit themselves. The following table should not be discussed with the students.

Interpretations

4.

Rock	Possible Minerals Present	Also present, but students may or may not include these in their lists
Basalt	Hornblende, Garnet, Olivine	Feldspar, Mica (Biotite)
Obsidian	Quartz, Hornblende	Actually there are no minerals present. Obsidian is a glass--cooled so rapidly that mineral crystals do not have time to form
Pumice	Quartz, Feldspar	Again, no minerals present--pumice is a glass
Scoria	Hornblende, Garnet Olivine	Feldspar, Mica (Biotite)
Rhyolite	Feldspar, Quartz, Hornblende	

5. The presence of bubbles or many small holes in the rock would indicate that gas occupied those spaces while the rock was forming.

6. Pumice and scoria contain bubble spaces.

INVESTIGATION 9.6: The Mouth of a River

Processes which change the landscape often occur in and near rivers. Procedures in this investigation may help you to understand some of these processes.

Materials (per team)

Clear quart bottle with lid
Ruler (metric)
Sand
Water

Procedures

A. Place about three tablespoonsful of sand in the bottle. Fill the bottle with water and then put the cap on firmly. Hold the bottle upright, then quickly turn it upside down and hold it perfectly still. Observe the bottle and its contents for about 30 seconds. Repeat several times.

Interpretations

1. Which particles settled out more rapidly?

2. Which particles stayed in suspension longest?

3. Under what conditions will sand remain suspended in water?

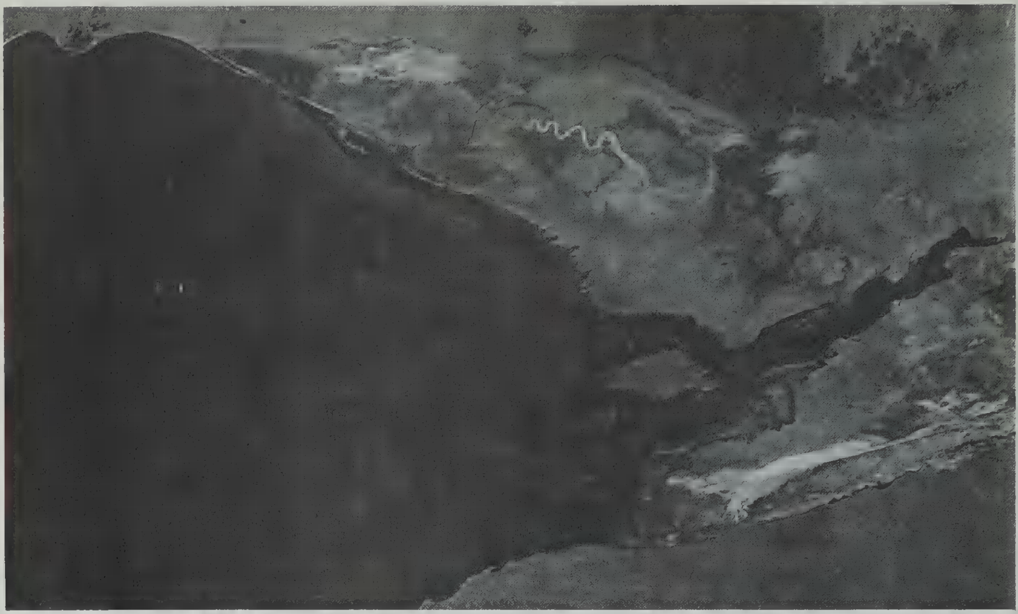


Figure 9.10. River Mouth.

Procedures (continued)

B. Examine the photograph (Figure 9.10) carefully. Refer to it as often as necessary in answering the following questions.

Interpretations

4. Why do you think the water in the left center part of the photograph appears lighter than the rest of the water?

5. How is the river related to this area of lighter appearing water?

6. What could prevent suspended material from settling out in the river?

7. Will the large particles or small particles of suspended material settle closer to the river mouth?

8. Do you think the body of water at the left of the photograph is a lake or an ocean?

9. Does this body of water have an unlimited ability to accept sand?

10. Where do you think the suspended material in the river came from?

<u>Procedures</u> (continued)

C. Pour water from the bottle until the remaining water is 10cm deep. Do this carefully to avoid losing sand. Then replace the bottle lid, shake the bottle and place it upright on the table. Allow the sand to settle. Use the metric rule to measure the height of the sand.

Interpretations

11. Roughly what fraction of the contents of the bottle is now sand?

Imagine a sandy river which is ten meters wide, three meters deep, and flowing at about the speed a person walks. In one year such a river would transport about one billion cubic meters of water.

Interpretations

12. If the imaginary river contained the same fraction of sand as did your bottle, how many cubic meters of sand would it transport in a year?

13. What effect do you think rivers have on the landscape?

Problems

1. Outline a procedure by which you could estimate the amount of water flowing in a river near your home.

2. Outline a procedure by which you could estimate the amounts of suspended material being carried by a river.

TEACHER MATERIAL

INVESTIGATION 9.6: The Mouth of a River

Materials

In some localities suitable sand may be found along rivers and beaches. Fine white sand for mortar, available at many building supply yards, is also quite satisfactory. Results are improved if coarse aquarium sand (#4), or equivalent, is added to the fine sand. Commercially available sands which have already been sorted (by screening or by water), may not demonstrate how sand can be sorted in a bottle. Garden soils tend to have a high proportion of very fine material which may obscure the result. Whatever you decide to use, it would be well to test the material first.

Procedures

A. See Figure T-9.6.

Figure T-9.6. Sorting Effect.

Interpretations

1. The larger particles settle out more rapidly. In some cases other tendencies may also be noticed. For example, it is possible that particles of a certain color are especially dense and may settle more rapidly than those of other colors, sizes being equal.

2. The finer particles tend to stay in suspension longer. A similar observation has been made concerning dust particles in air. (see page 241)

3. Sand will remain suspended only if the water is agitated. The larger particles, to remain in suspension, require greater agitation.

<u>Procedures</u> (continued)

B. No comment.

Interpretations

4. This water contains suspended material (which scatters light to the camera more effectively than does the clearer water adjacent to it).

5. The river is the source of the water containing suspended material.

6. The motion of the water in the river provided the agitation needed to keep the material suspended.

7. The larger particles will settle closer to the river mouth. As in the bottle, the smaller particles will settle more slowly and have the opportunity to drift farther.

8. There is probably not sufficient evidence to tell whether the body is a lake or an ocean. The question is raised in order to bring out the fact that rivers can deposit sediment in either fresh water or salt water.

9. For practical purposes oceans have unlimited capacities to accept sand. Lakes, being smaller, have more limited capacities. In geological terms, lakes are thought of as being relatively young. Had they been in existence for long periods of time they would have been completely filled with sediment.

10. Responses will vary. Accept all answers at this time.

Procedures (continued)

C. No comment.

Interpretations

11. Answers will vary.

The volume for one year is calculated by multiplying the width of the river times its depth times rate of flow times the length of a year.

Interpretations

12. Answers will vary. Each student's response to Interpretation 11 should be multiplied by the one billion.

13. Rivers carry considerable amounts of material from higher areas to lower ones. It is estimated that the rivers of the United States are carrying sufficient

weathered material to lower the landscape by 2.4 inches every 1,000 years.

Problems

1. The statement following Interpretation 11 may suggest a method to some students. Allowance should be made for varying rates of flow at different times of the year.

2. A bottle, bucket, or other container could be filled from the river. The material in suspension should be allowed to settle and the ratio of suspended material to water estimated.

In addition to its suspended load, a river may carry considerable amounts of dissolved minerals and large quantities of "bed load." This latter is moved along close to the bottom of the river and might be missed in the sampling procedure suggested above.

As the speed of a stream increases during periods of heavy run-off, its ability to transport material rises at an exponential rate. Estimates for one river show a maximum flow of 1,000 times that of minimum, and a suspended sediment load at maximum which is 100,000 times the load at low water!

INVESTIGATION 9.7: Sedimentary Rocks

Sedimentary rocks are made of materials that came from the destruction of previously existing rocks. When deposited material is cemented together by pressure and chemical action, the material formed is called sedimentary rock. A study of sedimentary rocks can provide information about conditions that existed long ago.

Materials (per team)

Sedimentary rock set
Mineral set
1 bottle dilute acid
1 hand lens
1 metric ruler

Procedures

A. Study the sedimentary rocks. Compare them with a labeled set to find the name of each type of rock.

B. Arrange the rocks in order according to the size of the fragments they contain. Record the names of the sedimentary rocks. The name of the rock containing the largest fragments should be listed first and the others according to decreasing particle size. Beside each name, make a small sketch of the sample, and record the average particle size in millimeters.

Interpretations

1. Which rock was formed from fragments that would settle out of rapidly moving water?

2. Which rock was formed from fragments that would settle out of slowly moving water?

3. Which rocks were most likely formed in an ocean or lake?

Procedures (continued)

C. For each type of rock, list the minerals which you think it probably contains.

D. Test each mineral with a drop of dilute acid. Observe and record any results and then blot the drop with a dry paper towel. CAUTION: This acid is corrosive. Be careful not to spill it.

E. Test each rock with a drop of dilute acid, and record any results. Then blot the drop with a dry paper towel.

Interpretations

4. Did Procedure E give information about the mineral content of the sedimentary rocks? If so, what additional information was gained?

Problems

1. The sedimentary rocks of a certain river basin consist mainly of sandstones. There are some conglomerates found in the northern part of the area and some shales in the south. Do you think the rivers which brought the sedimentary material to the area flowed from the north or from the south?

TEACHER MATERIAL

INVESTIGATION 9.7: Sedimentary Rocks

The emphasis of this investigation should be on the relationship between the processes that produce sedimentation and the sedimentary rocks. The student text states that sedimentary rocks are derived from pre-existing rocks. This is not strictly true since some limestones are deposited from water solution.

Materials

Sedimentary rock set: Conglomerate, sandstone, shale, limestone.

Mineral set: Quartz, feldspar, mica, olivine, hornblende, garnet, and calcite. (The mineral set is the same as for volcanic rocks, with the addition of calcite.)

In addition to the team sets there should be one or more labeled set of each type.

Dilute acid: add 10ml of concentrated hydrochloric acid to 90ml of water and pour 10ml into a dropper bottle for each team. CAUTION: Hydrochloric acid is corrosive. Be careful not to breathe the fumes or spill any of the concentrated acid on you.

Hand lens: the one-inch focal length lens can be used.

Procedures

A. No comment.

B. The rocks arranged by fragment size are:

Rock	Size
Conglomerate	larger than 2mm
Sandstone	2mm to 0.1mm
Shale	smaller than 0.1mm
Limestone	too small to see

Interpretations

1. The fragments in conglomerate could have settled from rapidly moving water.

2. The fragments in sandstone could have settled from slowly moving water.

3. Shale and limestone were most likely formed in a lake or ocean.

Procedures (continued)

C. The mineral content depends on the particular samples. If the fragments are light colored, students should list the light colored minerals. The shale may contain dark minerals, or its dark color may result from the carbon of included organic material.

D. Calcite reacts with acid to give off a gas (CO_2). Other minerals do not react.

E. Limestone reacts with acid to give off a gas. Other rocks should not react.

Interpretations

4. Procedure E indicates that limestone contains calcite, and that the other sedimentary rocks in the set do not contain calcite.

Problems

1. The rivers probably flowed from the north. The coarser rocks would then have been deposited closer to the river mouths where the water was still moving. If the area under consideration is a large one, the additional distance the material was transported would result in its being worn to finer sizes as rivers carried it to the southern end of the area.

EARTH BUILDING PROCESSES

At first, shoreline terraces, volcanoes, and stream mouths may not appear to have much in common. However, they were selected to be among the first topics in this section of the course because of one thing they do share: they are evidence that certain parts of the earth's solid surface are either rising or are being built up by having material deposited upon them. The ocean floor near a river mouth comes closer to the surface as suspended material settles onto it. Entire regions of some coasts appear to be rising. Volcanoes and the land surrounding them may rise many feet in relatively few years as lava and volcanic ash accumulate. For example, the volcano Mauna Loa, in Hawaii, rests on a base covering 5,000 square miles of sea floor. On this base is piled 10,000 cubic miles of volcanic rock rising to a total height, measured from sea floor to summit, of 30,000 feet. Thus, in one sense, the volcano Mauna Loa is the tallest mountain in the world.

In other regions there are different processes at work which appear to be elevating parts of the earth's surface. From your study of fossils you have reason to believe that the earth has been in existence for a very long time. Are the processes that build up the height of the land the only ones at work? Would the earth's surface be as we now see it if only these processes have continued for long periods of time?

When high mountains and low areas are all taken into consideration, the average height of the land is found to be only about 2,700 feet above sea level. Have the land-building processes started only recently? Or are there also earth-leveling processes at work?

MEANDERING AND BRAIDING

In a recent investigation you observed the effects of shaking water and sand together in a bottle. When you stopped shaking the bottle the water did not stop moving immediately. Typically, the water will continue to swirl about for a few seconds until friction within the water and against the sides of the container gradually brings it to a standstill. At the same time this is happening, the suspended material is settling out. The first particles to settle, while the water is still in fairly rapid motion, are the larger ones. As the water moves less and less rapidly, finer and still finer particles settle.

This sort of behavior is similar to what happens in an actual river. The more rapidly a river flows, the more suspended material it can carry. When the river is flowing gently, less material can be held in suspension. As a result, the amount of material that a river transports is not constant.

Generally, rivers tend to erode (wear away) banks and beds most actively in their headwaters, to transport material throughout their lengths, and to deposit material near their mouths. Also, it can be said that erosion, transportation and deposition all depend upon how rapidly the water moves.

Figure 9.11 shows a curve in a river. All three processes, erosion, transportation and deposition, may be going on in this one area and at one time. The muddy appearance of the water suggests that it is transporting suspended material. Along the outside bank the water is moving more rapidly than around the shorter, inside edge of the curve. Around this outer edge of the curve (at the right of the photograph), the fast moving water is

Figure 9.11. Curve in River.

undercutting the bank and acquiring more material for its suspended load. Along the inner bank, suspended material is being deposited from the slower water. The result of these three things happening is that the course of the river is shifting slowly toward the outside bank. It is also likely that the river will erode the downstream part of the outer bank more rapidly. This results from the fact that the river runs more directly into this part of the bank. Over a period of time the path of the river may change noticeably. This changing of paths is illustrated in Figure 9.12. in which fragments of former river courses can be seen.

Rivers such as these, which wind back and forth, are said to meander (wander). Do you think that rivers are more likely to meander in places where their courses are

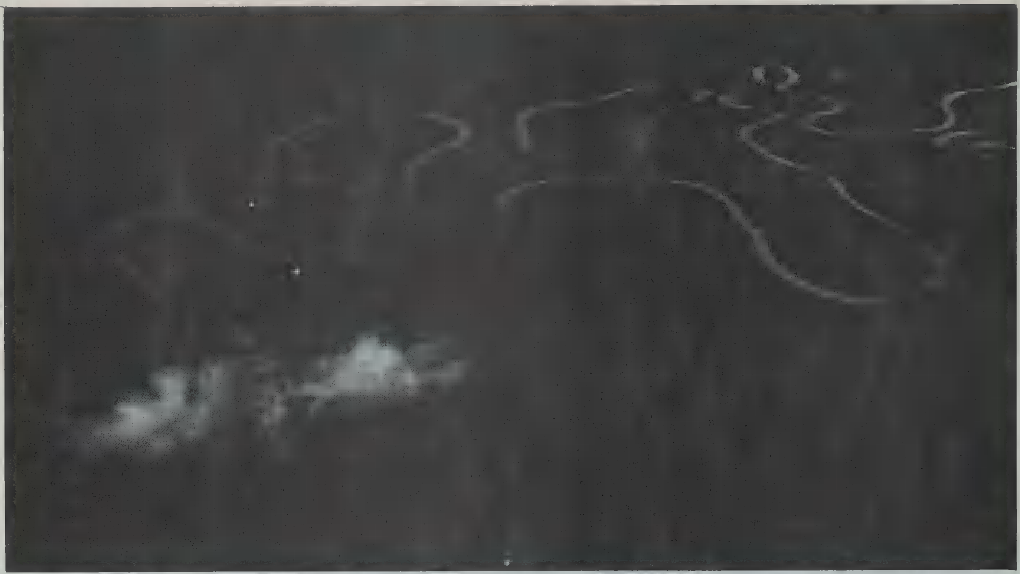


Figure 9.12. Meandering River.

steep or in places where they flow across nearly level ground? As the river shifts its path, a valley much wider than the actual stream width may be cut. Old terraces which represent former levels of the valley floor can often be seen above the present river level, as in Figure 9.11.

During times of high water the river may flood and spread out to cover large parts of its valley. From the shallow, slow-moving water far from the main course of the stream, fine silt is deposited. Near the banks of the main river channel, where the flood water is rapidly losing speed, thicker deposits of coarser sand and gravel may be laid down. These form natural levees which tend to keep the river within its banks during later floods.

Another case in which a river is eroding, transporting and depositing material simultaneously is shown in the lower right part of Figure 9.13. Here the river is said to be "braided." It has broken into many small channels which tend to rejoin and then split again.

If there are streams near your home or school, look at them for evidence of braiding or meandering. Even water running in the gutters of city streets after a rain may show one or the other of these patterns.

A river is not a simple thing. It must flow downhill, following valleys rather than ridges; yet the activity of the river helps determine where the ridges and valleys will be. This interaction between rivers and landscapes is one of the most widespread, most often repeated, and most interesting aspects of geology.

Figure 9.13. Braided Stream Bed.

TEACHER MATERIAL

MEANDERING AND BRAIDING

This selection, dealing with rivers, serves as a bridge between the processes which build up the land and the processes which level the land. It also points out the difficulty of categorizing geologic agents, since rivers serve both to tear down and to build up the land.

The term "erode" is used for the first time in this selection. If the word is not familiar to students, explain that it implies breaking up of coarse material and transportation of the resulting finer substance. The term "weathering" refers to processes which break rocks down into smaller units, either physically or chemically, without their subsequent removal. Thus, development of soil from underlying rock would be called weathering, whereas the breaking up of rock and its removal (as by a river) would be termed erosion.

The unanswered question relating to steepness of river courses can be discussed in class. If no consensus develops, students may be encouraged to look through magazines and books for photographs of meandering and non-meandering rivers. From these it should become apparent that meandering is a characteristic of rivers which flow over nearly level surfaces. Over steeper ground rivers follow straighter courses. In the extreme case, the most perfectly straight river would be a waterfall.

The dynamics of meandering are somewhat complicated and are described in Scientific American (June, 1966). The problems associated with braiding are not brought up in the text, but could serve as an example of an unresolved question in geology. Under just what conditions will a stream braid?

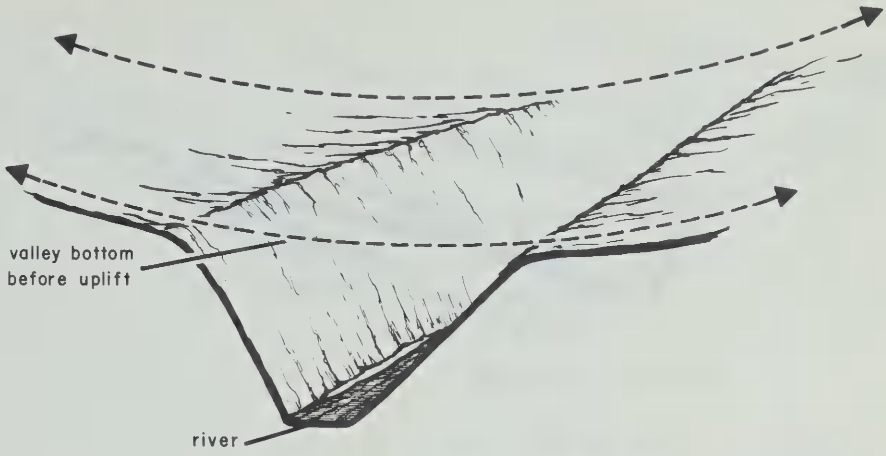


Figure T-9.7. Terraces Matched.

It seems likely that the final answer will involve both the slope and the nature of the material being transported, but as yet no complete and widely accepted analysis has been given.

Similarities and differences between stream and sea terraces can also serve as a topic for discussion, both types of terrace are cut by moving water. Whereas the sea terraces give evidence for elevation of the land relative to the ocean, the presence of river terraces may or may not indicate that the land in which they are carved has been elevated since formation of the terraces. If terraces on opposite sides of a river valley match in elevation (see Figure T-9.7) it seems likely that their level indicates a former, stable level of the floor of the valley. Subsequent uplift may have resulted in the acceleration of cutting by the river ("rejuvenation") until it once again eroded the land down close to its "base level" and ceased rapid cutting. On the other hand, terraces which do not match in elevation, but alternate, may have resulted without uplift. As the stream erodes

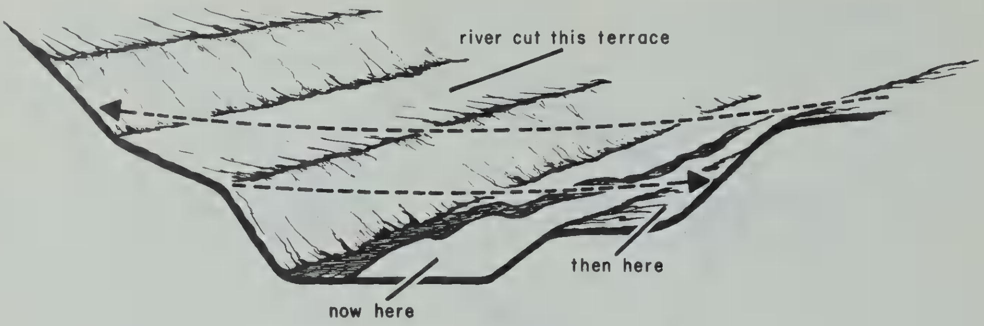


Figure T-9.8. Terraces Not Matched.

its way into the valley its path sweeps from side to side leaving such terraces (see Figure T-9.8).

In addition to the activity of the river, the types of rock present and the structures in them may have effects on the drainage pattern. This subject will be considered by students at a later time.

INVESTIGATION 9.8: Random Flow

Imagine rain falling on a smooth, sloping area of the earth's surface. Some of the drops soak into the surface, and others evaporate back into the atmosphere. The rest of the drops flow along the surface. Each moves downslope until it comes to some small obstacle. Will the drop then pass to the left or to the right of the obstacle? It is not possible to predict this. Such unpredictable events are said to be random. In this investigation you will produce some random paths.

Materials (per team)

Die
Quadrille paper

Procedures

A. Select a direction on the paper to represent downslope. Represent this direction by a short arrow drawn parallel to and near either of the shorter sides of the paper.

B. Place about 40 dots at random on the sheet of paper. Each dot should be located at a corner of one of the small squares ruled on the paper. The dots should be spaced fairly uniformly, but there should be no order or pattern to them. The dots will represent drops which will move down the surface according to the following rules:

Rules:

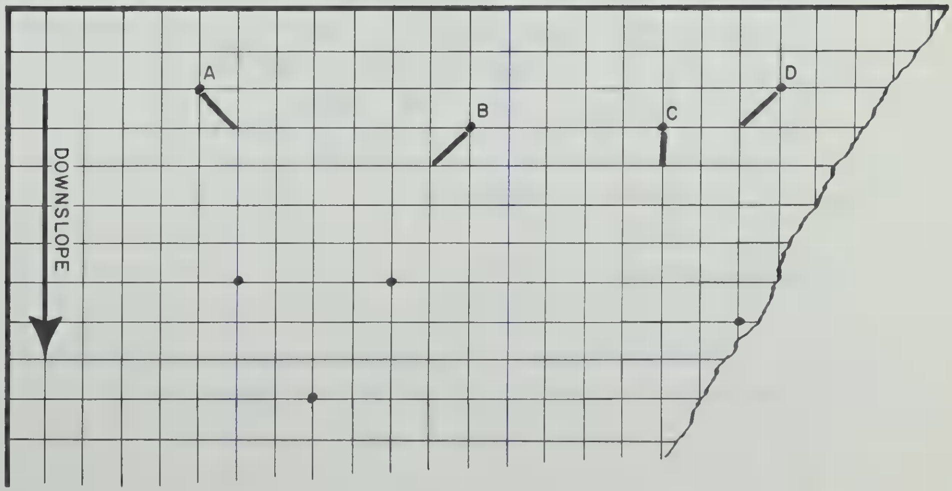
i. In its turn each drop is moved one space and its path is marked by a pencil line on the paper.

ii. Before it is moved the drop's path is determined by rolling the die. A roll of 1 or 2 on the die determines that the path will be diagonally downslope to the left, a 3 or 4 that it will be directly downslope, and a 5 or 6 that it will be diagonally downslope to the right. (Note that the number on the die indicates direction only, and not distance.) See Figure 9.14.

iii. In general, upslope dots should be rolled for and moved before lower dots are moved. Do not roll for or move downslope dots until all upper dots have progressed down to their level.

iv. Once a drop intersects the path or location of another drop the two move together, and their path is represented by two pencil lines side-by-side. A single roll of the die will determine the direction of their joint move. If a third drop joins in, the 3 will thereafter move together, and their path is marked by 3 parallel lines, etc.

Figure 9.14. Directions of Moves.



v. Other things being equal, larger amounts of water move more readily down a slope than do smaller amounts. In order to account for this: The length of a move is determined by the number of dots represented in that move. Single drops move one space each roll. Two drops flowing together move two spaces in the direction determined by a single roll of the die, etc.

vi. If it appears that a group of dots moving together may intersect the path of a smaller number of dots, the larger group should be moved first even though the smaller number is upslope. This will prevent the crossing of streams, something which does not occur in nature.

Procedures (continued)

C. Roll the die and draw in paths for the dots until all have moved off the sheet. Compare your results to Figure 9.15, a map of an actual drainage pattern.

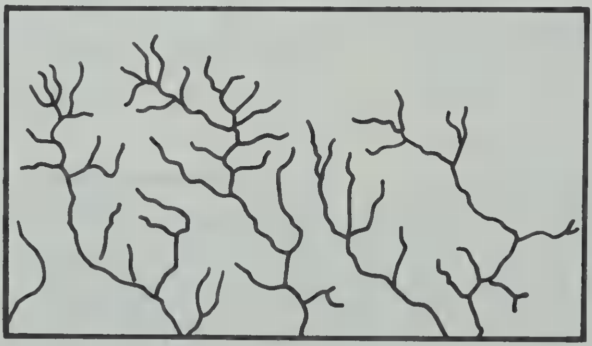


Figure 9.15. Dendritic Pattern.

Interpretations

1. In what ways does the pattern produced by moving the dots resemble the drainage pattern of Figure 9.15?

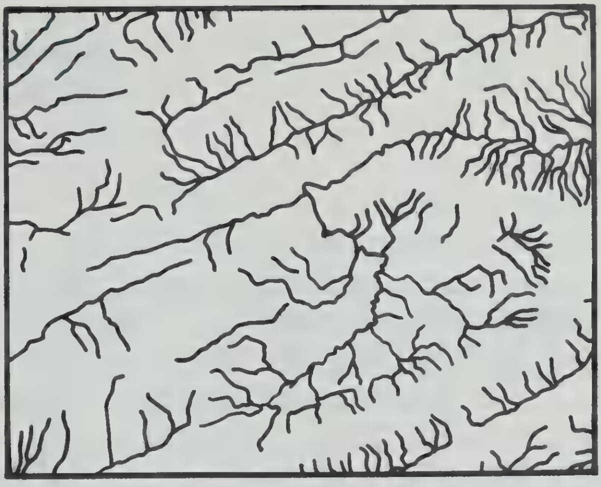


Figure 9.16. Trellis Pattern.

2. What might account for these similarities?

3. In what ways does the pattern you produced differ from the drainage pattern of Figure 9.15?

4. How might the rules be changed to produce a pattern that corresponds more closely to the drainage pattern?

5. Why do you think the area shown in Figure 9.16 has a drainage pattern which is so different from those considered earlier in the investigation?

TEACHER MATERIAL

INVESTIGATION 9.8: Random Flow

The paths produced in this investigation will not be completely random since they, like actual stream paths, have a non-random tendency to move downslope. The unpredictable turns to left or right are random.

The printed rules for this game make the game appear more complicated than it actually is. In order to avoid discouraging students by confronting them with the lengthy set of rules, you may wish to demonstrate the game in class. As soon as students understand the rules they can be allowed to start their own games. The games may be started in class and finished as homework.

A single sheet may be worked out by one student, or by two or three. (Once started, two students working together can complete one game in about 30 minutes.)

As a variation, you might prepare ditto sheets with dots and grid lines. Though starting with identical sheets, each group of students will end up with a different pattern. The different patterns emphasize the random nature of the process.

Materials

You may wish to provide each team with a paper or plastic cup. With these, the die need not be thrown, but may be shaken in the cup with a hand over the top and then observed while still in the cup.

Quadrille paper is available with varying numbers of lines per inch. Ruling of four to the inch is quite satisfactory.

Procedures

A.-B. No comment.

C. Figure T-9.9 shows a typical pattern.

Figure T-9.9. Completed Game.

Interpretations

1. The patterns generated here resemble stream patterns in several ways: Both show a distinct downslope trend with random changes in direction. In both cases paths merge to form larger paths. Larger paths tend to travel greater distances before changing direction. Students may think of others.

2. Statements which describe the behavior of actual streams have been translated into rules which determine the behavior of the paths in the investigation.

3. Actual paths are less angular than those produced in the investigation. Smaller streams have a non-random tendency to flow toward larger streams and join them at nearly right angles. (This is due to the fact that the downslope direction is locally altered as the larger streams produce deep channels.) Students may note other differences.

4. After being sketched in and located, changes in direction could be shown as more gentle curves with larger streams showing curvature of greater radius. This would help correct the first disparity noted in the responses to Interpretation 3. Accept all possibilities.

The purpose of the investigation is to cause students to think about the factors which influence the development of a drainage system, that is, the "rules" to which actual streams adhere. If possible, encourage discussion along these lines.

5. Since the pattern of the figure is distinctly different, drainage must have developed with different starting conditions or with the water behaving in different ways under the same conditions. The former appears to be the case. Instead of being a ". . . smooth, sloping area . . ." the area of Figure 9.16 is crossed by parallel lines of resistant rock. This is the subject of the next reading selection.

ANOTHER STREAM PATTERN

A "dendritic" stream pattern may cover thousands of square kilometers of the earth's surface. One can also develop in a road cut, in a vacant lot, or in some other small area. In the last investigation you were able to develop a pattern which resembled a dendritic stream pattern. Several assumptions were made early in that investigation: It was assumed that the rain fell on a smooth, sloping area. It was also assumed that when a stream came to an obstacle it would not be possible to predict whether the stream would pass it to the left or to the right.

If a stream flowed on a slope which was not evenly sloping, it might be possible to predict its behavior. Predictable behavior is not random. Stream patterns formed under such conditions would not be dendritic.

The stream pattern shown in Figure 9.16 developed in an area in which there were long parallel bands of easily eroded rock between more resistant bands. As might be predicted, valleys developed in the weaker material and the outcroppings of resistant rock remained as ridges. Thus the major streams of the area flow along parallel courses. The tributaries (smaller streams) flow down the sides of the ridges and join the larger rivers at nearly right angles. Such a system is known as a "trellis" pattern.

Notice that in some places a river will not follow the general trend of the ridges and valleys but instead cut through one of the resistant ridges to join the next parallel river. How was the river able to leave its valley?

Possibly the course of the river was already established before the ridge existed and then the ridge rose slowly up under it. Under such conditions the river might be able to continue on its course, eroding the ridge material as rapidly as it rose. A somewhat similar situation would

be one in which the entire drainage surface was once at a higher level than that now seen. As the level of the land was lowered by the action of the streams, the streams encountered the underlying bands of weak and resistant rock. Smaller, less powerful streams were forced into courses running along the easily eroded valleys. Larger, more powerful rivers continued in their courses, even across bands of resistant rock.

A different situation is that in which a tributary of one river (River I in Figure 9.17a) erodes its way upslope until it has cut entirely through a ridge. A second stream (River II in Figure 9.17b) is "captured" by the tributary, flows through the ridge and joins River I. This process is known as stream "piracy."

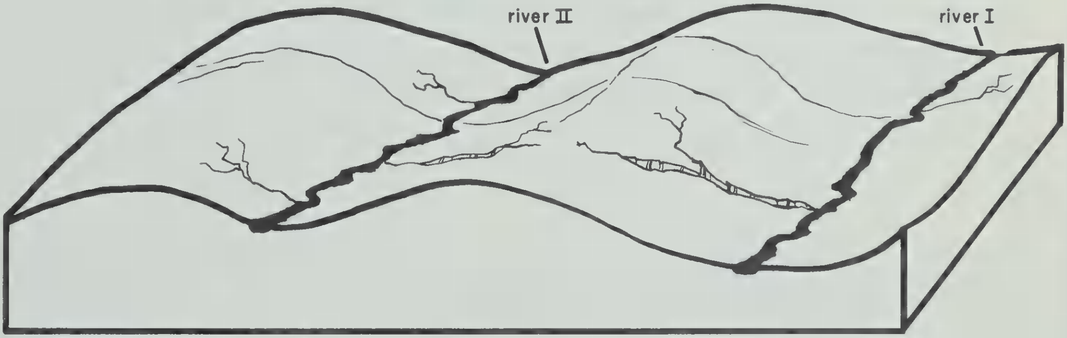


Figure 9.17a. Stream Piracy.

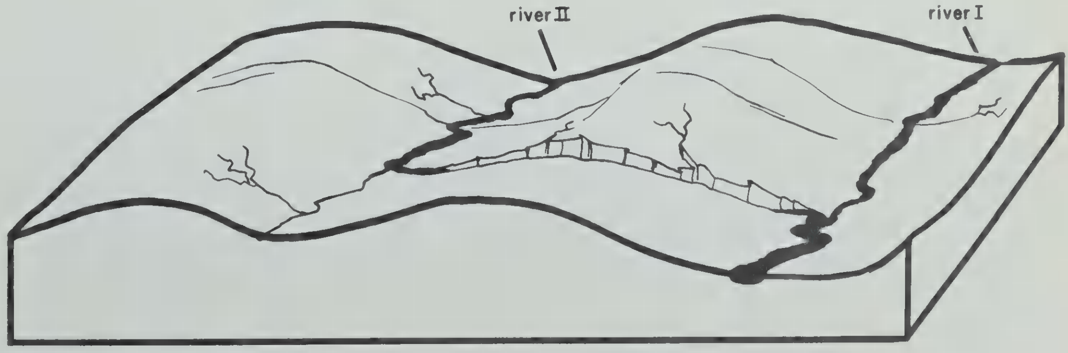


Figure 9.17b.

TEACHER MATERIAL

ANOTHER STREAM PATTERN

Landscapes and drainage patterns of the sort described in this selection can be simulated in a demonstration with a thick towel. The towel is laid flat on a smooth surface and then shaped into long, parallel wrinkles. It should become apparent that streams will tend to follow the valleys formed. Manipulation of the towel can produce ridges which are interrupted by "water gaps" through which rivers pass. A plunging (tilted) anticline can be simulated by producing a single, large fold and then pulling apart corners of the towel at one end of the anticline. The repetition of beds at the surface resulting from folding of a sedimentary series can be shown by wrinkling a stack of colored towels and viewing from the side.

INVESTIGATION 9.9: Defining a Problem

In many of the investigations which you have performed you have been asked a question. Then procedures were outlined. As you followed the procedures you made observations. Proper interpretation of the observations may have led to a model (a useful way of thinking) which made the original question less puzzling. In some investigations the questions have been stated directly. In others you may have been well on your way to the answer to a question before you really understood what the problem was. In this investigation you will attempt to recognize and state a problem.

Materials

None

Procedures

A. Examine Figure 9.18. Pay particular attention to the fencé.

Figure 9.18. Fence.

Interpretations

1. State a question about the fence.

2. What assumption must be made about the way the fence was built?

3. If necessary, re-write your question (Interpretation 1) to include the assumption.

<u>Procedures</u> (continued)

B. When you have stated your question as clearly as you can, compare your question to questions stated by other members of the class.

Interpretations

4. List several possible answers to your question. Try to include at least one geological solution to the problem.

5. Prepare a list of procedures which might lead to accepting or rejecting the answers of Interpretation 4.

<u>Procedures</u> (continued)

C. Examine Figures 9.19 and 9.20.

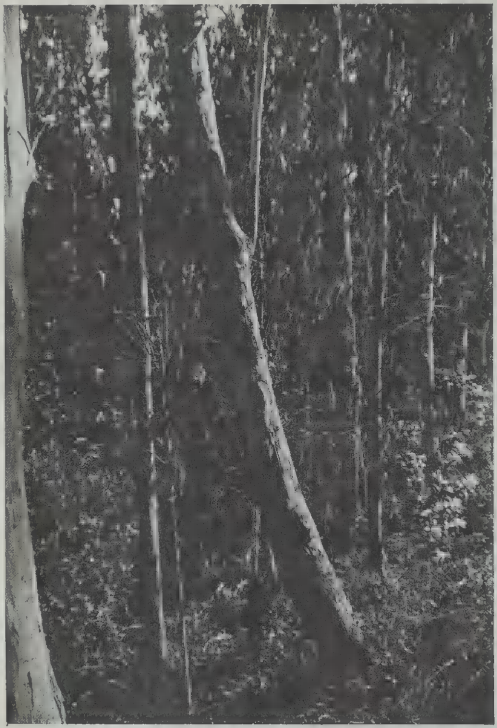


Figure 9.19. Tree.

Figure 9.20. Road Cut.

Interpretations

6. Assuming that the features shown in Figures 9.18, 9.19, and 9.20 all result from the same process, what do you think was the process?

TEACHER
MATERIAL

INVESTIGATION 9.9: Defining a Problem

You may wish to allow small groups of students to compare responses (as called for in Procedure B) as soon as several students are ready to do so. Or you may want students to wait after completing Interpretation 3 until all are ready to participate in a class-wide discussion. Be sure that each student has had sufficient time to formulate his own question before comparisons are made, or a major aim of the investigation will be missed.

Procedures

A. No comment.

Interpretations

1. A typical response, with geological significance, might be, "Why are the fence posts tilted?" Give clues, if necessary, as to the type of question desired without giving away that this is the problem in which we are interested.

2. It is reasonable to assume that the fence posts were vertical when the fence was built.

3. A question of the form, "What has caused the fence posts to tilt?" includes the assumption. If this assumption is not at least implied, answers to the question could include the trivial response, "Perhaps it was built that way."

Procedures (continued)

B. See comment in introduction to this investigation.

Interpretations

4. It is hard to predict all responses, though it seems likely that students may include:

"Animals have leaned against the posts."

"Wind has blown them over."

"The soil has shifted."

"Something ran into the fence."

At this point we wish to include as many responses as we possibly can.

5. Responses could include:

"Interview property owners. Ask them if the posts were originally vertical, if animals were ever kept in fields bounded by the fence, etc."

"Look for other fences to see whether or not tilted fences are a common phenomenon."

"Check with the weather bureau to find out the direction of prevailing winds."

"Observe fenced fields in which animals are kept to see whether animals do lean against posts."

"Follow the fence to a place where it crosses level ground to see whether it is tilted there or only on sloping ground."

"Look for examples of fences that tilt upslope."

"Continue to observe these same posts to see whether tilt increases."

"Examine other objects in the same area in order to see if only fence posts are affected."

Procedures (continued)

C. No comment.

Interpretations

6. Figure 9.19 shows a tree with a bent trunk and Figure 9.20 a road cut in which the upper ends of sedimentary beds are bent slightly in a downslope direction. Various suggestions as to the origin of each condition should be solicited. Encourage students to examine suggested processes which could explain all three of the observed features.

"Soil creep" is a phenomenon which is consistent in providing explanations for all three. Soil creep refers to a very widespread process in which weathered surface material moves slowly down hillsides. The process occurs more rapidly in places in which the soil is alternately saturated and dried, and on steeper slopes. Although the amount of creep is not often more than a few centimeters per year, the widespread nature of the process makes it very significant in moving large amounts of weathered material downslope.

Soil at the surface creeps more rapidly than does that at depths of several centimeters. This is illustrated directly by the photograph of the curved ends of the sedimentary beds. It is expressed less directly by the fact that the fence posts are tilted instead of having been displaced directly downslope. The curved tree trunk has probably resulted from a steady tilting of the base of the trunk as the upper part of the tree continuously grows directly upward.

WEATHERING AND SOIL

Rocks exposed to the atmosphere slowly change. Air and water can react with minerals to alter or even remove them. In one of the more common reactions, minerals which contain iron are broken down.

You are probably familiar with rust. Iron which is exposed to air, especially if water is present, soon develops a red-brown coating of rust. The iron combines with oxygen in the air and becomes a new substance, iron oxide. Similar changes occur in rocks which are exposed to air, particularly if water is present. By the process of "oxidation" (or rusting) iron changes to rust.

Weathering is the name of the process by which rocks change to soil. Rocks which have been exposed to the atmosphere for greater lengths of time tend to be more deeply weathered than newly exposed rocks. Over them will be deeper covers of soil. Some minerals are more easily changed chemically than are others. In the presence of air and moisture feldspar will change to clay minerals. On the other hand, quartz particles are resistant to chemical changes.

Plants have a distinct effect in the development of soils. Simple plants known as lichens can grow on unweathered rock. As soon as rock starts to weather, other, more complicated types of plants can become established. Plants remove some materials from developing soil. Living and decaying plants also add to the soil. Besides the chemical effects which plants have on the soil, their roots may act upon it physically. Some kinds of plant roots can work their way between rocks and force them apart. Soil which might otherwise be washed away, may be held together by a dense mat of plant roots.

Along with the plants, there will be insects, bacteria and animals living in the soil, burrowing in it, and grazing on the plants it supports. The soil is a zone in which there is an intense and complicated interaction between the original rock, plants, animals and the atmosphere.

Water tends to drain rapidly from soils which form on hillsides and remain longer in those which lie in valley bottoms. As a result the development of soils in the two types of locations will follow different lines and proceed at different rates.

Of all the factors affecting soil development, climate appears to be the most critical. Soils developed from the same type of rock in temperate and tropic areas will be quite different from each other. Soils formed under the same conditions of climate will tend to be similar even if the rocks from which they develop are quite different.

Weathering converts solid rock into materials which can be eroded by wind and running water. Soil, the product of weathering, provides a growing place for plants and enables the earth to support large populations of both plants and animals.

TEACHER MATERIAL

WEATHERING AND SOIL

Weathering is the process by which rock is broken into smaller particles without being changed in location. Weathering may result from chemical or physical processes or, most commonly, from a combination of the two. Erosion includes weathering and also removal of products of weathering.

The five factors involved in soil formation are: rock type, climate, slope, plant and animal activities, and time.

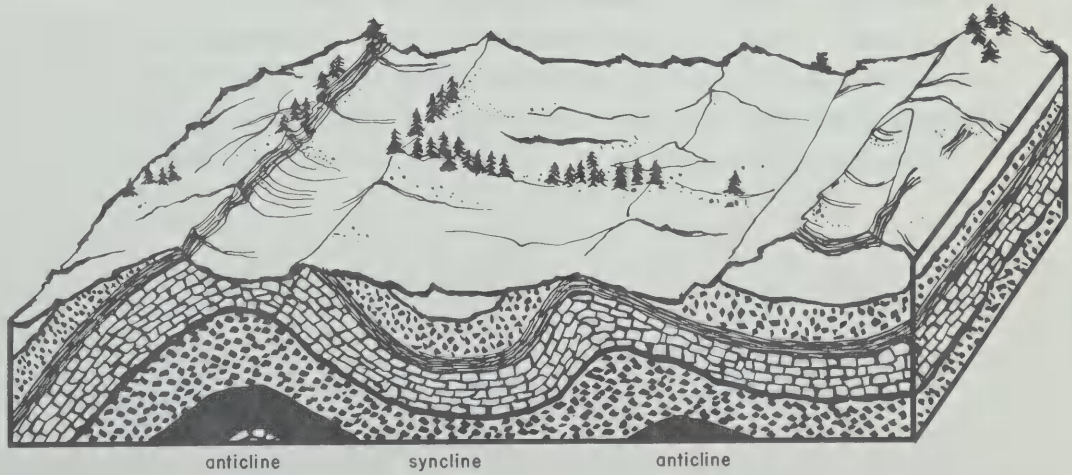
No detailed knowledge of soils or the processes that produce them is expected of students. Instead, it is hoped that they will develop a general feeling for the importance of weathering in development of landscape. Without weathering, as described in the student text, little could be accomplished by streams and by soil creep and other processes that supply material to the streams.

BENDING--UP OR DOWN

The parallel bands of resistant and weak rocks mentioned earlier are a common feature in parts of North America. Figure 9.21 shows different effects that folded beds may have on the landscape. At the left of the figure is an anticline. An anticline is a fold in sedimentary rocks in which the edges of the structure are bent down and away from a central line. The uppermost part of the anticline has been eroded away to form a valley. A single resistant bed is exposed in two different places forming parallel ridges.

A syncline is another type of folded sedimentary structure. In synclines the beds are bowed downward in the center. Again, one resistant layer of rock may appear at the surface in several places producing parallel ridges. At the right of Figure 9.21 resistant rock forms a ridge. This occurs despite the fact that in that area the beds are bowed down in a syncline.

Figure 9.21. Folded Beds.



Knowing that sedimentary rocks can be folded into anticlines and synclines may help you to understand some landscapes and stream patterns you see. Keep in mind, however, that the tops of the folds (anticlines) do not necessarily correspond to ridges in the present landscape. Look again at Figure 9.21 to see a structure in which the very crest of an anticline is a valley. Remember, too, that the sedimentary rocks forming the anticlines and synclines were originally laid down in horizontal layers. The folding which produced the anticlines and synclines probably occurred deep beneath the surface. This is suggested by the fact that often layers of rock have been bent without breaking. In the section on geophysics you will consider evidence for different behavior of rocks when they are under great pressure.

It often happens that molten rock cools to form granite deep beneath areas where there are ranges of folded mountains. Close to areas in which granite is being formed heat and pressure may metamorphose (change) other rocks. Movements of the crust may then bring the granite and metamorphic rocks close to or above sea level. When the overlying rock is removed by erosion, the granite can be seen. The drainage patterns formed in granitic areas are understandably different from those formed in folded mountains.

INVESTIGATION 9.10: Igneous Rocks

Volcanic rocks are not the only ones formed from melted material. All rocks which solidify from a molten state are called igneous [ig-nee-us] rocks. A comparison of different rocks can give information about the conditions under which they were formed.

Materials (per team)

Igneous rock set
Mineral set
Magnifying lens

Procedures

A. Examine the igneous rocks and classify them into groups according to the conditions in which you think they were formed. In your notebook, record what you think the formation conditions were and the names of the rocks in each group.

Interpretations

1. Which rocks were formed under the greatest pressure and which under the least pressure. Give reasons to support your answer.

Procedures (continued)

B. Examine the rocks not previously studied and try to determine their mineral content. Use the magnifying lens if necessary.

Interpretations

2. Compared to the volcanic rocks, is it easier or harder to identify the mineral content of the two new igneous rocks? Why?

3. What minerals do you think are in the two new igneous rocks?

4. How could you test to see whether igneous rocks contain calcite?

5. Do any of the igneous rocks contain calcite?

INVESTIGATION 9.10: Igneous Rocks

Two kinds of rocks containing large crystals have been added to the set of igneous rocks previously studied. The purpose is to have the students recognize that large crystals indicate slow cooling. This is used as evidence for earth building processes since slow cooling indicates that the rocks were formed far below the surface and have since been elevated to the surface.

Materials

Igneous rock set: Scoria, pumice, rhyolite, basalt, obsidian, granite, gabbro.

Mineral set: Quartz, feldspar, mica, olivine, hornblende, garnet, calcite.

Hand lens: The one-inch focal length lens can be used.

Dilute hydrochloric acid (Although not specified in the student materials, Interpretation 5 should lead them to request it.)

Procedures

A. Possible student response:

Cooled Rapidly with gas present	Cooled Rapidly	Cooled Slowly
Scoria	Basalt	Granite
Pumice	Obsidian	Gabbro
	Rhyolite	

Interpretations

1. Since bubbles were able to form in pumice and scoria, these rocks were probably under the least pressure.

Granite and gabbro were probably formed under high pressure. The reasoning leading to this conclusion might run as follows: Large grain sizes in these rocks suggest that they cooled slowly. If they had been formed at or near the surface, they could have lost heat rapidly into the air. Since they cooled slowly they must have been at great depth. The weight of all of the material on top of them would exert a lot of pressure.

<u>Procedures</u> (continued)

B. No comment.

Interpretations

2. It is easier to determine the mineral content of the two new rocks because the mineral crystals in them are big enough to see.

3. The minerals probably in the two new igneous rocks:
granite--feldspar, hornblende, quartz, biotite
gabbro--feldspar (?), hornblende, olivine, garnet.

Point out to students that rhyolite and granite have the same chemical composition. The difference in appearance between them results from different cooling rates. Gabbro and basalt also have similar compositions, the basalt differing in appearance as a result of faster cooling.

4. If they contain calcite, they should react with acid to give off gas.

5. In order to answer this question, students will have to obtain dilute acid and test each igneous rock.

No igneous rock contains calcite.

INVESTIGATION 9.11: Metamorphic Rocks

Rocks which are altered as a result of heat and pressure are described as metamorphic rocks. Metamorphic rocks may be formed from sedimentary or igneous rocks. Inspection of metamorphic rocks can give information about the degree of metamorphism which has taken place.

Materials (per team)

- Metamorphic rock set
- Mineral set
- Magnifying lens

Procedures

A. Examine the metamorphic rocks and attempt to arrange them into an order of increasing shininess. Assuming that all of these rocks were once shale-like, decide which of them has been most altered.

Interpretations

1. Do all sides of metamorphic rocks reflect light equally?

2. What mineral do you know which might account for the ability of metamorphic rocks to reflect light in this manner?

3. Can you recognize this mineral in any of the rocks? If so, in which rock or rocks is it found?

4. What other minerals, if any, can you recognize in the metamorphic rocks? In which of the rocks do these minerals appear?

5. Which of the metamorphic rocks most closely resembles granite?

6. In what ways does it resemble granite?

7. How does it differ from granite?

8. What sort of structure appears to be characteristic of metamorphic rocks?

9. How might this structure be related to the pressure which caused the metamorphism?

10. List the metamorphic rocks in order, starting the list with the rock which most resembles shale and ending with the most highly metamorphosed.

INVESTIGATION 9.11: Metamorphic Rocks

Metamorphic rocks may also be formed from previously existing metamorphic rocks. This point is not made in the student text.

Materials

The metamorphic rock set should include: slate, phyllite, schist and gneiss.

Shale and granite specimens from the other sets should be available for comparison.

Both biotite and muscovite micas, hornblende, quartz and garnet from the mineral sets should be on hand.

Procedures

A. One labeled set of rocks can be set out for identification purposes.

Interpretations

1. Metamorphic rocks, particularly schist, have a tendency to reflect light better from one side than another.

2. Mica is highly reflective on its cleavage faces and dull around the edges of its books.

3. Mica is a characteristic constituent of metamorphic rocks. It should be identifiable in gneiss and schist and possibly in the phyllite.

INVESTIGATION 9.12: Freezing Water

In some climates, weathering and erosion are largely dependent upon the formation of ice from water. You are already familiar with some of the properties of water. In this investigation you will consider differences in volume of water as it changes from a liquid to a solid.

Materials (per team)

- Beaker
- Metric ruler
- Test tube
- Marking pencil (grease pencil)
- Ice
- Table salt

Procedures

A. Prepare a chart similar to Figure 9.22 in your notebook.

1	Height of water in test tube	_____cm
2	Height of ice in test tube	_____cm
3	Difference in height	_____cm
4	Percentage difference	_____%

Figure 9.22.

B. Using the marking pencil, label the test tube with the initials of one member of your team. Half fill the test tube with tap water.

C. With the marking pencil, draw a line on the test tube to show the level of the water in it.

Measure the height of the water column and record your answer on line 1 of your chart.

D. Half fill the beaker with crushed ice. Sprinkle about two tablespoons of salt over the ice and mix the ice and salt together.

E. Place the test tube of water in the ice-salt mixture so that it is surrounded by ice. Observe the water in the test tube as it cools.

F. When the water solidifies, remove the test tube and measure the height of the column of ice. Record your answer on line 2 of your chart.

G. Calculate the difference in height between the column of liquid water and the column of ice. Record your answer on line 3 of the chart. Calculate the percentage difference and enter your answer on line 4 of your chart.

Interpretations

1. What was the change in volume as the liquid water changed to ice?

2. By what percent did the volume of the water change?

3. If 100 cubic centimeters of ice melted, what volume of liquid water would be formed?

4. Why would it be dangerous to freeze a tightly sealed container filled with water?

TEACHER MATERIAL

INVESTIGATION 9.12: Freezing Water

Materials

"Pyrex" type beakers or metal cans should be used for the ice bath. Common jars may break when subjected to the low temperatures of the ice-salt mixture.

Procedures

A.-C. No comment.

D.-E. If ice-salt baths cannot be used you can place the test tubes in the freezing compartment of a refrigerator overnight. Schools with cafeterias usually have a large freezer or locker that you might use.

F. No comment.

G. If students are not familiar with calculating percentage values, an estimate will suffice.

Interpretations

1. In a sample run, a column of water 5cm in height produced a column of ice 5.3cm high, a change of 0.3cm.

2. $$\frac{\text{3mm change}}{\text{50mm starting height}} = .06$$

$.06 \times 100 = 6\%$ change

3. 100cc of ice reduced 6% would result in 94cc of liquid water.

4. Pressure produced as a result of the increase in volume could shatter the container.

THE WORK OF ICE

When water changes from its liquid form to ice it occupies more space. If it was formed in a closed space, the ice could exert a very great pressure on its surroundings. Under ideal conditions this pressure can be as great as 30,000 pounds per square inch!

Think of the effect such a pressure might have. Water freezing while trapped in small cracks in a rock can fracture the rock. The tremendous pressure mentioned above is probably never reached when water freezes under natural conditions (perhaps you can think why), but a force great enough to split rocks is probably quite common. This process is known as "frost wedging." Figure 9.23 shows rocks which may have been shattered by frost wedging.

Figure 9.23. Weathering in High Mountains.

The process of soil creep can be hastened by freezing and thawing of water in the soil. In Figure 9.24 the path of a soil particle is shown. When water in the soil freezes and expands, the particle is squeezed. It cannot move up or down slope because other particles are in the way. Instead, it moves out from the slope. When the soil thaws the soil particle moves directly down under the influence of gravity. The particle does not come back to its original position, but to one farther downslope.

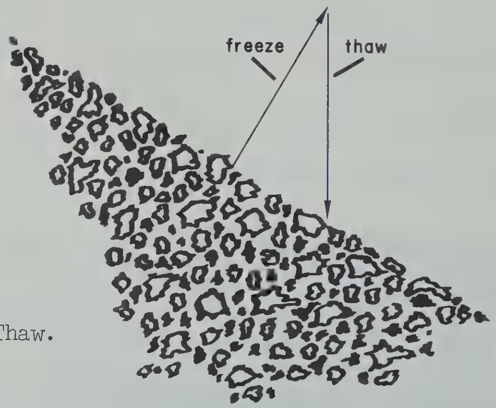


Figure 9.24.
Effect of Freeze and Thaw.

The effects of gravity and of running water in shaping the landscape are relatively easy to see. In daily life there are constant reminders of the force of gravity. Rivers are common enough so that practically everyone has seen a river of some size and can think about its effect on the land.

But glaciers are not common in most parts of North America. Perhaps this helps to explain why the very important part that glaciers have taken in shaping the North American landscape was not recognized until about 100 years ago.

A glacier can form only in an area in which more snow falls than can be removed by melting and evaporation. When snow has accumulated to a depth of 200 feet or so the

weight of the overlying snow will cause the deeper snow to turn into ice. This ice, under pressure, is able to flow slowly without cracking or breaking. The pull of gravity can cause these large bodies of ice to move down a slope or valley. Such a large, moving body of ice is called a glacier. Valley glaciers, like those found in Alaska, originate in higher areas where there is heavy snowfall. Once in motion a glacier may continue down to well below the elevation at which snow is plentiful. Sooner or later, the snout (front end) of the glacier reaches a place which is warm enough to cause it to melt. A glacier such as the one shown in Figure 9.25 will occupy the same general location for hundreds of years, constantly forming at its head, moving down valley, and melting at its snout.

Figure 9.25. The Mendenhall Glacier.

Ice sheets, found now only on Greenland and in Antarctica, are composed of great thicknesses of ice. The ice is so thick (thousands of feet) that no distinct slope is necessary in order to cause the ice to flow. The weight of ice in the central region of snow accumulation exerts enough pressure so that the edges of the glacier move outward. See Figure 9.26.

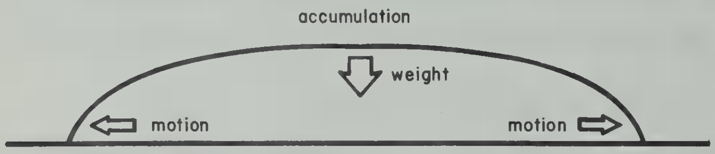


Figure 9.26. Movement in Ice Cap.

What unusual effects do glaciers have in shaping the landscape? What evidence is there for believing that large parts of the United States and Canada were once covered by ice?

As you have observed, sedimentary deposits formed in water tend to be sorted. The larger particles are deposited as soon as the transporting water starts to slow down. Finer material settles out in different locations, after the water in which it was suspended has come to a near standstill. Material which has been transported by ice does not show this sorting. See Figure 9.27. Large rocks and tiny sand grains are carried side-by-side atop the moving ice or frozen into the body of the glacier. As the ice melts, or when the transported material has been carried to the snout of the glacier, large and small fragments alike are dropped in the same deposit. There is no opportunity for sorting or layering. Unsorted deposits of ice-transported material are called moraine. In North America this type of deposit is found north of an irregular line extending as far south as Topeka, Kansas, and Louisville, Kentucky. Figure 9.28 shows old moraine deposits in Wisconsin.

Figure 9.27. Fresh Moraine.

Figure 9.28. Old Moraine.

Large, isolated boulders can be found in many parts of the Northern and Eastern United States. The boulders are too large to have been moved by rivers. In many cases they are composed of rock types which are not found locally. It is likely that long ago, the boulders were carried to their present locations by glaciers. Generally, the source area for these "erratic" boulders is to the north, suggesting that the glaciers came from that direction.

Lakes are relatively short-lived features because of their tendency to accumulate sediment until they are filled in. In areas where other glacial evidence is present, lakes are numerous. Some lakes have resulted from the damming of rivers by morainal deposits. Others have been scoured out of the underlying rock by glacial movement. Immense plains, now extensively used for growing wheat and other grains were formed from the sediments which accumulated on the bottoms of older glacial lakes.

In many places rocks have been characteristically polished and scratched. The polishing and scratching occurred when rocks imbedded in glacial ice were dragged over the stationary bedrock. See Figure 9.29.

Figure 9.29.
Scratches in Bedrock.

Outwash plains are located beyond the limit to which the glaciers themselves reached. These areas are covered with material which was transported first by glaciers and then by rushing streams from the melting glaciers. These outwash plains may show kettles, small lakes formed when depressions filled with water. The depressions resulted from the melting of masses of ice buried in the sediment.

Many otherwise puzzling features of the North American landscape can be explained in terms of glaciers. The melting of vast ice sheets must have produced enormous quantities of water. Some of the melt water appears to have drained into inland basins of the western states, forming temporary lakes of great extent. The melt water added to the oceans has raised their level by 130 meters in the past 15,000 years.

But a model which is created to explain one set of observations often produces problems of its own. The various features described in this selection can be accounted for by thinking in terms of glaciers. Similar features dating from the Permian indicate that at that time glaciers were also common. However, the distribution of glaciers during Permian time is somewhat unusual. There were apparently glaciers in South America, South Africa, and Australia. Since all of these locations are close to the South Pole it seems reasonable to think of glaciers spreading north and leaving their traces. But India, which is north of the equator, was also glaciated during Permian time. This seems odd because areas adjacent to India were then experiencing temperate to tropical climates. Why should one isolated area develop extensive glaciers? It seems that there will always be interesting problems for those who study geology.

TEACHER MATERIAL

THE WORK OF ICE

Under natural conditions water in cracks of rocks would probably freeze over the surface producing a "lid" of sorts. However, this lid would most likely be forced upward, releasing pressure, long before the full 30,000 pounds per square inch was developed. Attempts by students to freeze liquids in closed containers should be discouraged for reasons of safety. It is well known that radiators not protected by anti-freeze can be damaged by the effects of expanding ice.

In a later investigation, "An Unusual Substance," students will produce a substance which has some of the physical characteristics of glacial ice. Ice near the surface of a glacier is not under sufficient pressure to flow and hence may fracture, producing "crevasses" or deep cracks.

Typical rates of movement for glaciers range from a few centimeters up to two meters per day. Glacial "surges" have been recorded, during which a glacier may move at 50m per day for limited periods of time.

Although glaciers are commonly involved in formation of lakes, students should not conclude that all lakes are glacial in origin. Lakes may also be formed by activity of faults, landslides, etc. The Great Lakes have doubtless been formed as a result of the Pleistocene glaciation, but their history is quite complicated. It involves the drainage system existing in pre-glacial times, glacial scouring, the formation of lakes between the receding ice front and end moraines, and depression of the crust as a result of the weight of the ice. It must be borne in mind that there were four major advances of ice, each involving minor

advances and retreats, and later advances tended to obscure the effects of earlier advances.

The deposits of outwash material are recognized as glacial in origin by the large quantities of striated and "faceted" rocks and glacial flour (finely powdered rock) in them. They must have been stream transported because of the evidence of sorting by size, but transportation must have been for short distances only. Otherwise, angular, faceted boulders would have been rounded in the process of being transported.

Glacial timetables are complicated to say the least. It seems fairly certain that the Pleistocene "Ice Age" started about 300,000 years ago. There were four major advances of ice, the last maximum occurring about 14,000-20,000 years ago. By roughly 6,000 years ago the ice sheets had essentially disappeared. Mountain glaciers of the present are not relics of the great ice age, but have originated within the past few thousand years. There have been numerous minor advances and retreats of glaciers in the past several hundred years. More details of the ice age itself and of more recent glacial activity are certain to be worked out in the future. Students should not be disturbed, rather they should expect, to read of changes and refinements in glacial timetables.

As these timetables are worked out in greater detail, the relationship of glacial lakes to the ice age will become more clear. Some geologists hold that the same heavy precipitation which produced the glaciers also provided water for glacial lakes. Others support the view expressed in the text. All agree that lakes existed at approximately the same time as the great ice sheets. If students have not already made the association, you should lead them toward relating the glacial lakes to the shoreline of Figure 9.5. It is shorelines such as this which indicate that the vast glacial lakes existed.

Encourage speculation on the matter of glaciers in India at a time when its present environs were experiencing more moderate climates. In the next section the notion of continental drift is introduced as a solution to problems involving various aspects of earth science. Students should be left with the feeling that Permian glaciation in India presents a problem. Within the next several weeks some of them may recognize that if India was once in a more southerly location, was glaciated there, and then drifted to its present latitude the glacial problem could be resolved.

Section Ten:

Seeking Larger Patterns

PREVIEW

While Section Nine dealt with geologic processes on small scale (structures within crystals) and intermediate scale (mountain building), Section Ten deals with the largest of geologic features and processes. In it, students consider models for the structure of the earth and for continental drift.

Following a short introductory selection, students observe possible "fits" between margins of continents. A laboratory involving floating blocks, followed by text presents evidence for the earth's having a crust of low density granitic material "floating" on a denser material.

Waves are introduced in order to make the evidence provided by earthquake waves more meaningful. Evidence provided by seismic records suggests that the earth consists of crust,mantle and core.

Laboratory work with magnets shows how paleomagnetic properties of rocks are useful in determining former locations

of continents. The paleomagnetic properties of actual rocks substantiate the idea that continents have not always occupied their present locations.

At this point students are expected to be aware of the advantages of thinking in terms of moving continents. Such motion would be consistent with observations concerning outlines of continents and prior locations of the magnetic pole. Students should also recognize that the rigidity of the mantle --as evidenced by its ability to transmit shear waves--appears inconsistent with movement of the continents.

A laboratory study of cornstarch paste shows that materials do exist which have the rigidity necessary for transmission of shear waves and the plasticity needed to allow for motion.

Text materials then show that the structure and location of mid-oceanic ridges suggest sea-floor spreading along trailing edges of moving continents. The leading edges of continental plates are identified by locations of mountain chains and the distribution of earthquake foci.

Continental drift, as summarized in this section, provides a good example of a model which is currently in a vigorous state of development.

Section Ten:

Seeking Larger Patterns

LARGE-SCALE FEATURES OF THE EARTH

Just what is geology? Included in it is the study of rocks and minerals. It includes the study of processes, such as erosion, which change the surface of the earth. Geology, in fact, deals with all of the earth, from its very center out to the air and water which cover it and help to shape its surface.

Geology includes very small-scale studies, such as searches for structure within single crystals. Geology includes studies of larger areas, measured in miles and hundreds of miles. One aspect of geology, geophysics, deals with very large-scale features of the earth. Geophysics involves entire oceans, whole continents, relationships between oceans and continents, and even features which are hundreds and thousands of miles within the earth.

Some geologists of the present day concern themselves with searches for oil, for ore minerals, and for building materials. These geologists are carrying on a very old tradition, for the cave men who used stone tools knew that some rocks provided better tools than others. Our terms for historical periods, "Bronze Age," "Iron Age," and the like, reflect the fact that man's ability to use minerals

has changed. Although they probably did not think of themselves as geologists, it is likely that there have always been men who were particularly good at finding the minerals needed by their societies. Thus the petroleum geologists and uranium prospectors of today are the latest in a long line of mineral seekers.

Geophysics, on the other hand, is a relatively new part of geology. True, speculation about the large-scale structure of the earth has gone on for centuries. But the rapid development of electronic tools, of satellites, of undersea probes, in the past thirty years has provided man with great amounts of observational evidence not previously available. With these new observations geophysicists are very rapidly building and revising models for the processes and structures of the earth. Geophysicists are working in a field for which there are no established traditions.

What sorts of problems do you think they are studying?

INVESTIGATION 10.1: A Continental Puzzle

Materials (per team)

- Thin paper
- Pencil
- Scissors

Procedures

A. Place a sheet of paper over the part of the map that shows the continent of Africa. Holding the paper steady with one hand, trace the edge of the continent. Do not include Madagascar or Arabia. Use the scissors to cut out the continent along the traced line.

B. Lay the cut-out of Africa on the map in your book. Move it up against the outline of the eastern edge of South America. Next, see whether the north-western edge of Africa fits aginst North America. Then test to see whether it can be shifted to make a better fit with Spain than it now does.

Interpretations

1. Make sketches in your notebook to show the best possible fit against each of the places suggested in Procedure B.

2. Can you suggest a way in which Africa might be made to fit both North America and South America?

3. If you were looking for evidence that Africa might once have been located in a different position, what might you look for?

4. List several reasons why you think it would NOT be likely that Africa was ever in contact with South America.

Figure 10.1. Africa and the Americas.

TEACHER MATERIAL

Figure T-10.1.

a. Africa and South America

b. Africa and North America

c. Africa and Spain

INVESTIGATION 10.1: A Continental Puzzle

Materials

You may wish to duplicate outline maps of the world on a ditto in order to save time. A large wall map or globe in the room will make it easier to discuss the problems involved.

Interpretations

1. Possible solutions are shown. There may well be others.

2. One way in which both fits could be imagined is by having the fits occur at different times, first one and then the other. Or since there are no instructions to the contrary, North America could also be moved. This can result in a solution somewhat as shown.

Figure T-10.2. Africa fits with North and South America.

Other techniques that lead to better fits can be mentioned but need not be discussed in depth. These include the selection of map projections other than the one in the book. Each projection produces its own distortions; perhaps the one given in the book makes it more difficult to fit the continents. Then there is the problem of what is meant by the "edge" of a continent. Students may have heard of the "continental shelf." This is a part of the continent that extends out under the ocean at relatively shallow depths before dropping abruptly to the deep ocean floor. By taking edge of the continent to mean the edge of the continental shelf instead of the sea shore a better fit can be obtained.

3. Several lines of evidence will be considered in future investigations. These include sea-floor spreading and the distribution of mountain ranges.

Students may also correctly suggest rock types that match on opposite sides of oceans, mountain ranges and other structures that match, plant and animal types (present day and fossil) that match, and others.

4. Be sure to stress that an idea such as moving continents does not gain widespread acceptance overnight. Alfred Wegener, a German who suggested the idea of moving continents in 1912, met sound opposition. What forces are large enough to move continents? How can solid rock move over the surface of the earth? Even if continents can move why didn't they find stable positions and settle there long ago?

These [illegible]
The outline [illegible]
[illegible]
Information [illegible]
outlined comes from [illegible]

[illegible] the five [illegible]

single block

1. Add water to the [illegible] to a depth of about 5cm. Place one of the blocks [illegible]
Measure the distance from the surface [illegible]

INVESTIGATION 10.2: Floating Blocks

There appear to be some interesting relationships between the outlines of different continents. Are these relationships simply a coincidence, or is there a reason for them? Information which may lead to an understanding of the outlines comes from a wide variety of sources. The first of these is a study of floating objects.

Materials (per team)

- Baking pan
- Wood blocks
- Centimeter rule
- Water

Procedures

A. Copy Figure 10.2 in your notebook.

Figure 10.2.

Number of Blocks	Height of Top	Depth of Bottom	Fraction Above Water
1			
2			
3			
4			

B. Add water to the baking pan to a depth of about 5cm. Place one of the blocks in the water. Measure the distance from the surface of the water to the top and to the bottom of the block. Enter the data in your table. Remove the block.

C. Form a stack of two blocks on your table or desk. Place the stack in the water. Repeat the measurements of Procedure B. Remove the blocks and record your measurements. Form stacks of three and then four blocks, placing each in the water, measuring and recording.

Interpretations

1. Why do you think wood is less dense than water?

2. Calculate the fraction of each stack of blocks which remains above water and enter results in your table.

3. On the average, what fraction of floating wood remains above the water?

4. Describe what you think would happen if the topmost of a stack of five floating blocks were removed.

5. Describe what you think would happen if one additional block were placed on top of a single block floating in water.

<u>Procedures</u> (continued)

D. Form a stack of five blocks, and place it in the pan of water next to a single block. Remove the topmost of the five blocks and place it on the single block.

Interpretations

6. What happened as Procedure D was performed?

7. Were your predictions made in Interpretations 4 and 5 correct?

<u>Procedures</u> (continued)

E. In your notebook make a sketch of a series of floating blocks. The view should be directly from the side. On the left show a stack of two blocks, next (touching it on the right) a single block, then four blocks and finally another single block. Label the wood "less dense" and the water "more dense."

TEACHER MATERIAL

INVESTIGATION 10.2: Floating Blocks

Materials

Flat, relatively thin blocks of uniform size and density will work best. Fir or pine of about 1cm x 9cm x 9cm, sprayed with shellac to prevent waterlogging, is quite satisfactory.

Any waterproof containers large enough to accommodate two or more blocks side by side may be used. The containers should also be deep enough to float a stack of five blocks.

Procedures

A.-C. No comment.

Interpretations

1. This can be concluded from the fact that the wood blocks float. If necessary, review the idea of density.

2. Student responses will vary depending upon the exact nature of the wood used. The "Fraction Above Water" can be expressed as a decimal or as a fraction. Values of about .3 to .5 (1/3 to 1/2) can be expected.

3. Student responses will vary.

4. Student responses will vary. Be sure that students make predictions before proceeding to the next part of the investigation.

5. Student responses will vary.

Procedures (continued)

D. No comment.

Interpretations

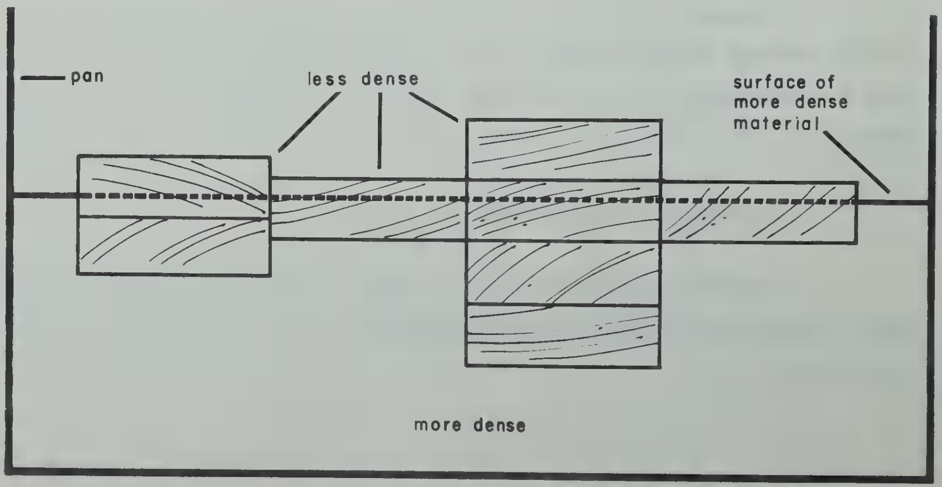
6. The remaining four blocks will rise until (after some oscillation) the "correct" fraction of the four blocks is exposed above the surface. This investigation may interest some students in a study of floating objects and buoyancy, a fine subsidiary study.

7. Student responses will vary.

Procedures (continued)

E. A typical response is shown in Figure T-10.3. Attention should be paid to the fraction of each stack which remains above the surface. This should be the average of the experimental results as expressed in Interpretation 2.

Figure T-10.3. Typical Result.



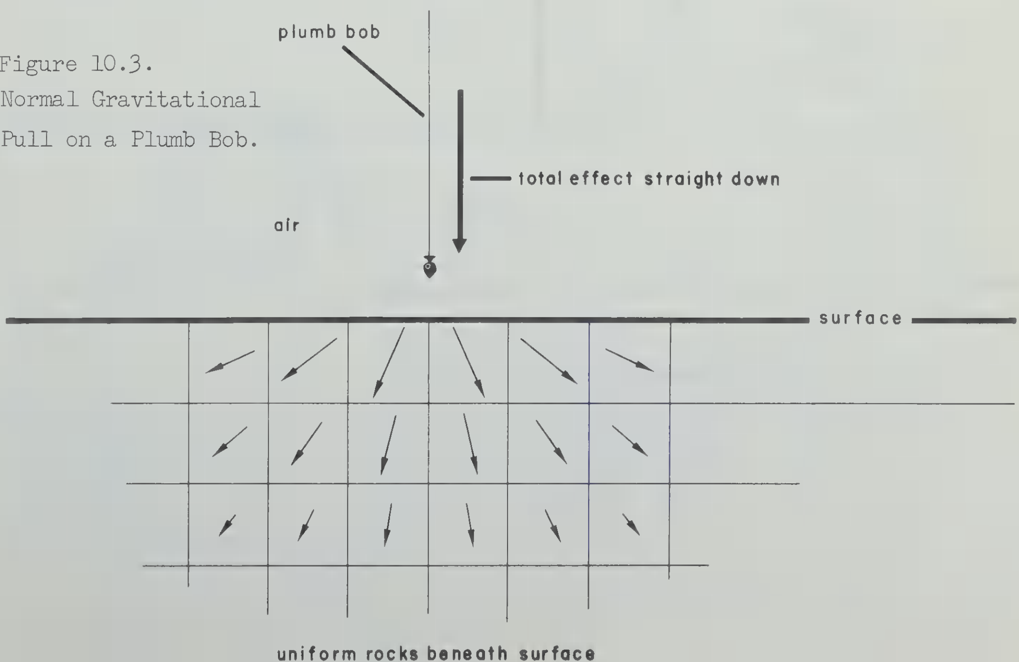
A MODEL FOR THE CRUST

During the late 1700's the French scientist Bouguer, working in the Andes of South America, made some puzzling observations. A plumb bob, used to establish the straight-down direction for some survey work, did not behave "properly." Instead of pointing straight down, the plumb bob seemed to point slightly away from the mountains. Similar observations were made near another large mountain range, the Himalaya.

What relationship could exist between floating blocks of wood and the behavior of a plumb bob? Everyday experience shows that all objects are attracted to the earth by gravity. The strength of this attraction to the earth is called the weight of an object. Carefully conducted investigations have shown that objects are not only attracted to the earth but also to each other. The strength of the attraction depends upon the closeness of the objects and the amount of material in each.

It is not just one part of the earth that causes the attraction; each part contributes. This is illustrated in Figure 10.3, in which the direction of a force is shown

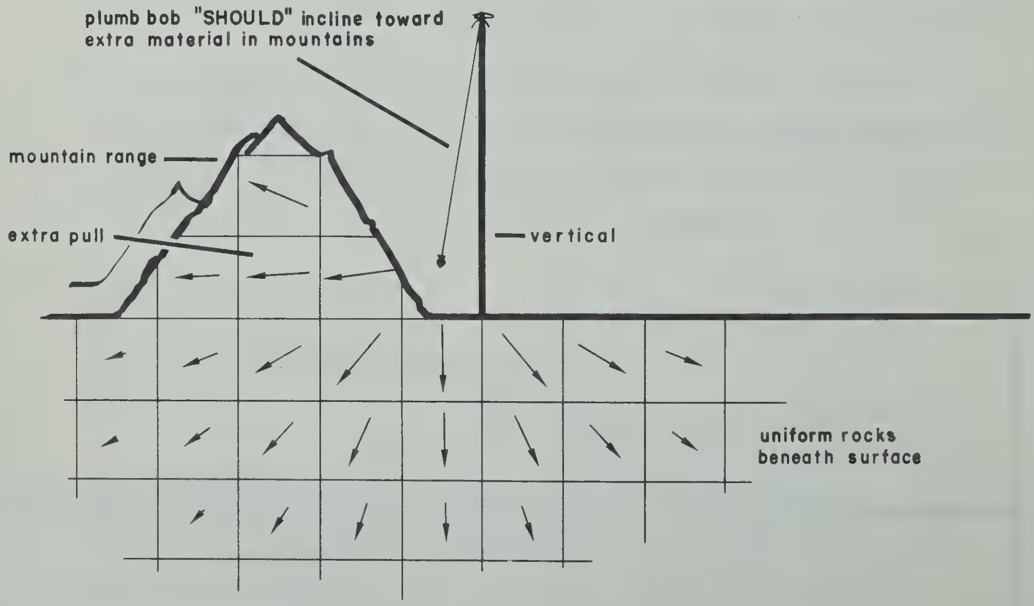
Figure 10.3. Normal Gravitational Pull on a Plumb Bob.



by the direction of an arrow. The strength of the force is indicated by the length of its arrow. The total effect of all bits of the earth is represented by the downward arrow beside the plumb bob. Note that for each force (such as A) that pulls the plumb bob to one side there is a balancing force (A') at the same distance on the other side. Figure 10.3 represents a normal situation, in which there are no unusual bodies of rock above or below the surface.

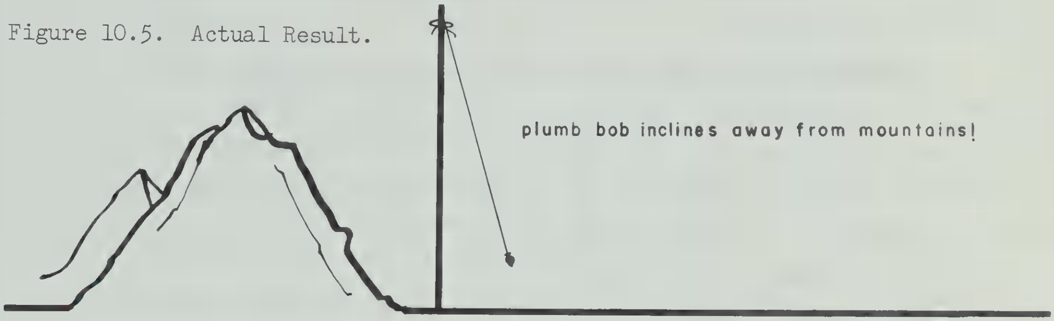
But suppose a large range of mountains is located to one side of the plumb bob. It might be expected that the extra material in the mountains would attract the plumb bob slightly and cause it to incline toward the mountains. This is illustrated in Figure 10.4.

Figure 10.4. Expected Result.



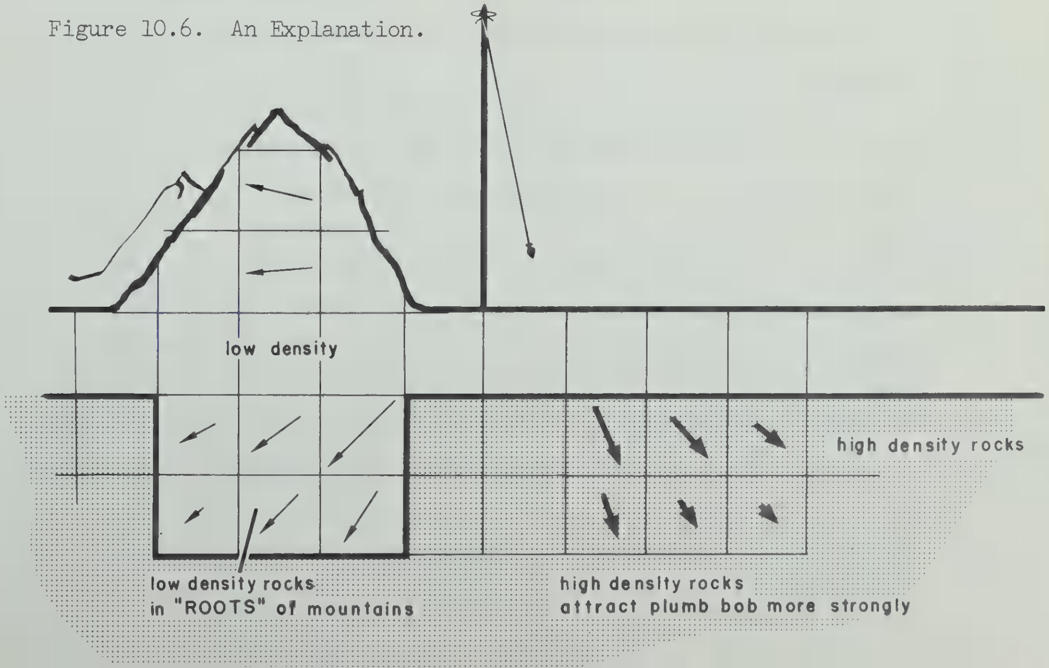
The actual effect, as noted by Bouguer and others, was that the plumb bob inclined away from the mountains. This effect is illustrated in Figure 10.5.

Figure 10.5. Actual Result.



There seemed to be nothing on the surface of the earth which could account for this behavior. What about below the surface? What conditions there could cause the strange behavior of the plumb bob? IF the crust of the earth consisted of a layer of low density rocks over a more dense layer, and IF under a mountain range low density rocks extended deeper than elsewhere, the effect could be explained. These conditions are shown in Figure 10.6.

Figure 10.6. An Explanation.



The low density rocks in and below the mountains pull the plumb bob weakly to the left. The more dense rocks under and to the right of the plumb bob pull strongly to the right. As a result the plumb bob inclines slightly away from the mountains.

Compare the sketch you prepared for Procedure E of the last investigation with Figure 10.6. Are there similarities? Is it possible to think of continents as floating on a more dense type of rock? Could mountains be thought of as having "roots" of low density rock? Would this way of thinking, this model, be consistent with other observations of the earth or only with observations of plumb bobs?

TEACHER
MATERIAL

A MODEL FOR THE CRUST

The force due to gravitational attraction is described by the relationship $F = GmM/r^2$, in which G is a constant, m and M the masses of the bodies involved, and r the distance of separation. Normally the attraction of two small objects for each other is masked by the far greater attraction of the earth for each of them. This results from the large mass of the earth.

The ideas outlined in the student text are commonly referred to as "isostasy." Columns of material extending from the atmosphere to deep within the earth should be of equal mass if a condition of equilibrium exists. One column may be composed of a greater height of less dense material and another of a lesser height of more dense material, but their total masses should be the same. A column of greater mass will have a tendency to sink, thereby decreasing its height; a column of lesser mass will rise until equilibrium is attained.

Gravimeters, devices which measure the intensity of the earth's gravitational field, have been highly refined and are an extremely useful tool in geophysics. The expected gravitational field is calculated for an area to be surveyed. The calculated intensity of the field is compared to measurements made with the gravimeter. Differences in the two values are referred to as "anomalies." Anomalies may represent ore bodies of high density, salt domes or other low density deposits, or deviations from isostatic balance. Less than normal gravitation is associated with areas of the crust which are rising, and higher gravity with areas of subsidence.

The question which closes the selection should not be answered directly at this time. Students will consider evidence for "floating" behavior of continents in the next selection.

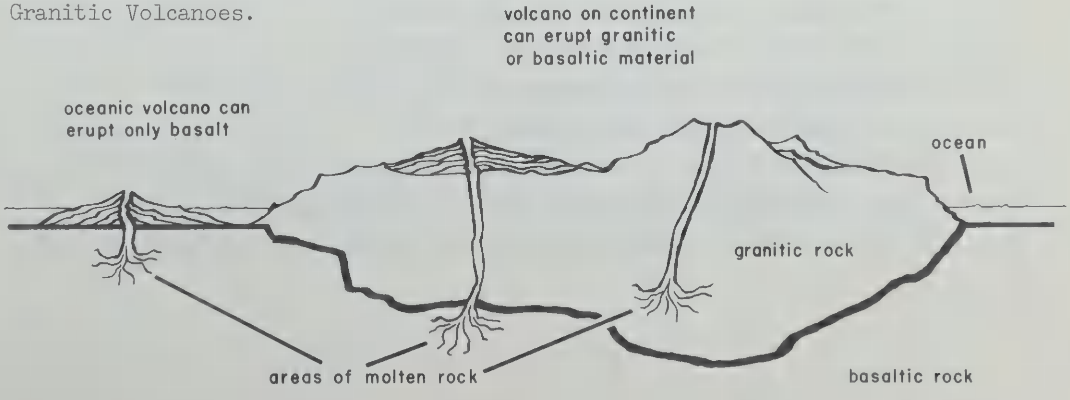
OTHER EVIDENCE OF A CRUST

The term "crust" refers to rocks and structures within about twenty miles of the surface of the earth. As you study earthquakes you will find reasons for thinking that beneath twenty miles the earth is sufficiently different to require a different term to describe it.

The behavior of plumb bobs near mountain ranges has led to an interesting model for the structure of the crust of the earth. This behavior can be understood if the crust is thought of as a thin layer of granitic rocks (thicker under mountains), underlain by more dense rocks. What other evidence supports this model? In the laboratory, the water represented a more dense material which surrounded and underlay the less dense material. Is there a corresponding material of high density surrounding and underlying the continents?

As you recall, volcanoes which are active on the continents or near them may erupt rhyolite, a low density granitic material. Or they may erupt basalt, a rock of higher density. On the other hand, volcanoes such as those in Hawaii, which are far from any continent, erupt only the higher density rocks, never a low density rock such as rhyolite. Can you think of a structure for the crust of the earth which would be consistent with this observation? Look at Figure 10.7. A structure such as

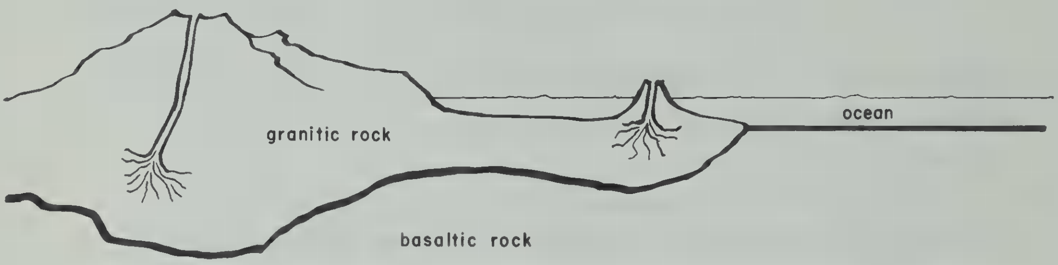
Figure 10.7. Basaltic and Granitic Volcanoes.



this would account for both types of lavas from continental volcanoes and the eruption of only basaltic lava from oceanic volcanoes.

How could Figure 10.7 be modified to account for volcanoes such as Mt. Pelée which, though surrounded by ocean, erupt low density material? Figure 10.8 suggests a possibility. If this type of view is accepted, the developing model will be consistent with the evidence provided by volcanoes.

Figure 10.8. A Granitic Island Volcano.



At this point it seems desirable to develop new, geologic definitions for ideas such as "ocean" and "continent." In the ordinary sense, continents end at the shoreline. A person who stands on a beach has land behind him and waves rolling in from a great expanse of salt water before him. He feels that he stands at the exact boundary between continent and ocean. But the nature of the rock beneath him does not change abruptly at this point. Hundreds of miles offshore there may be islands such as Martinique whose rocks are more continental (granitic) than oceanic in character.

Numerous measurements of depths indicate that the oceans are relatively shallow around continents. The shallow water, several hundred feet in depth, may extend

outward for a few or a few hundred miles. This zone covered by shallow sea water is known as the "continental shelf." Beyond this there is generally a steep drop, known as the "continental slope," to depths of several thousand feet. It is here, at the continental slope, that oceans truly begin.

None of the evidence presented thus far supports the idea that continents are floating. Perhaps they are solid granitic masses resting upon solid basalt. What evidence, if any, lends strength to the idea of granite floating on a non-rigid layer of basaltic material?

When you added weight to a floating wood block in Investigation 10.2, the block sank deeper. A possible similarity does occur as a crustal feature of the earth. A "geosyncline" is an area in which sediments have been deposited over a long period of time. In some of these areas sediments have accumulated to depths of ten miles. Does this mean that there was once an ocean 50,000 feet deep which was filled over a period of time? Probably not. Fossils in the sediments of a geosyncline often show that all of the rocks were deposited at depths of 1,000 feet or less. The suggestion is that as the sedimentary material accumulated the underlying rock sank slowly. The bottom surface of the column of sedimentary rocks thus became lower while the upper surface remained at a relatively shallow depth.

When you removed weight from the top of a stack of floating wood blocks the remainder of the stack rose. Some areas of the earth's crust are now rising, very rapidly as geologic processes go. In parts of Canada and in Scandinavia the rise has amounted to several hundred feet in the past few thousand years and is continuing at one or two meters per century. It is as if a great load had been removed suddenly from a huge, floating block. But what could have been extremely heavy and yet have been

removed so suddenly, much more quickly than the erosion of rock can proceed? The areas in which the rising occurs and the length of time involved may provide clues.

Further evidence concerning the structure of the crust can be gained through a study of waves. Waves will be the next topic you will consider.

TEACHER
MATERIAL

OTHER EVIDENCE OF A CRUST

The rising of large areas in Canada and in Scandinavia is a consequence of the melting of the ice caps of the last ice age. The weight of thousands of feet of glacial ice has apparently depressed these regions. With removal of the ice they are springing back.

Students should not think that all uplift which is presently in progress is a result of the same cause. Erosional lowering of mountains may cause the mountainous areas to be lightened and give them a tendency to rise further.

Forces associated with the leading edges of drifting continents are given as a mechanism for rising mountain chains in the selection on this subject at the end of this section.

of large areas in Canada and in Scandinavia [illegible]
[illegible] sence of the melting of the ice caps of the last
Ice age. The weight of thousands of feet of glacial ice
has apparently depressed these regions. With [illegible]
the ice they are springing back.

Students should [illegible] think that all [illegible] which
[illegible] in progress is a result of the same cause.
[illegible] lowering [illegible] not [illegible] may cause the [illegible]
be lightened and give it a tendency [illegible]

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[illegible] are given [illegible] [illegible] [illegible]
[illegible] is the elevation on the [illegible] [illegible]

INVESTIGATION 10.3: Studying Waves

The deepest mines dug into the crust of the earth have allowed men to penetrate to about 10,000 feet beneath the surface. Drill holes, such as those made for oil wells, have produced samples of rock from more than twice that depth. Movements of the earth's crust have brought to the surface rocks which were once at depths of several miles. Volcanoes erupt lavas from considerable depths. Information about conditions at even greater depths can be gained from a study of waves. This investigation will provide you with information which will be useful in understanding how waves can provide such information.

Materials (per team)

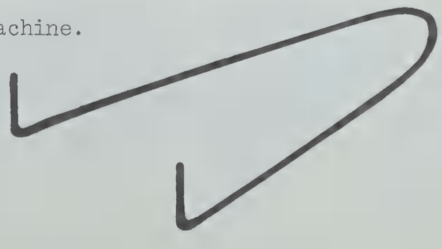
- Wire coat hanger
- Rubber bands
- Paper clips
- Five ceramic magnets
- Masking tape
- Scissors

An S-Wave Machine

Procedures

A. Use wire-cutters to remove the handle of the hanger. Bend the hanger to the approximate shape shown in Figure 10.9, with the upright ends about 50cm apart.

Figure 10.9. Frame for S-Wave Machine.



B. Cut and tie rubber bands to form a single strand of rubber about 60cm long when not stretched. Place large paper clips on the rubber strand about 5cm apart.

C. Tie the ends of the strand to the ends of the coat hanger as shown in Figure 10.10. Tension is correct when the middle of the strand sags about 1cm beneath the ends. Adjust the paper clips so that when they are not in motion they will remain approximately horizontal.

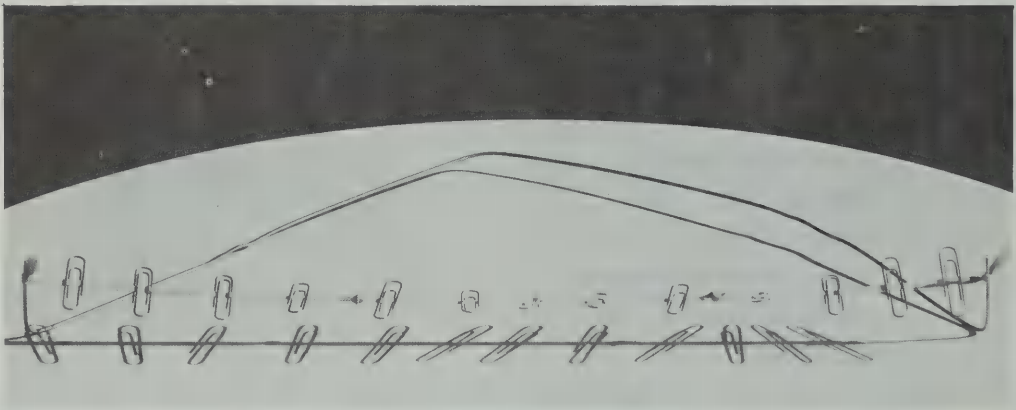


Figure 10.10. S-Wave Machine.

D. Allow the clips to come to rest. Stop each with a fingertip, if necessary. Tap down lightly on the tip of an end clip.

Interpretations

1. Describe the results of Procedure D.

2. Was it possible to see something move away from the paper clip which was depressed (pushed down)?

3. If so, what do you think it was?

Procedures (continued)

E. Allow the clips to come to rest. Focus your attention on the near end of one of the clips which is close to the center of the strand. Depress an end clip as in Procedure D.

Interpretations

4. Describe the behavior of the centrally located clip.

A P-Wave Machine

Procedures (continued)

F. Cut five pieces of masking tape approximately 1cm by 5cm in size. Place them adhesive side up on your worktable about 2cm apart. Use two strips of masking tape to hold the five original strips in place.

G. Set a ceramic magnet in place on each of the five tape strips as shown in Figure 10.11. The magnets

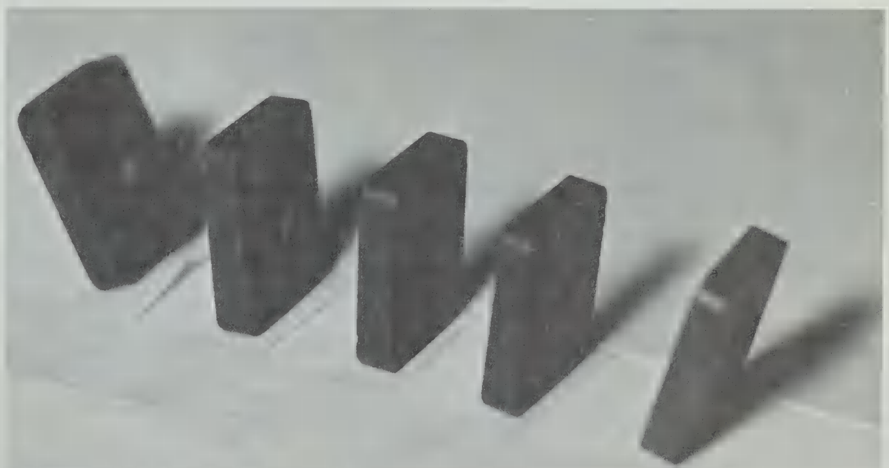


Figure 10.11. P-Wave Machine.

should be faced in such a way that each magnet repels the magnets next to it. Press the magnets firmly against the tape to hold them in position. CAUTION: Ceramic magnets may chip or crack if allowed to "jump" together.

H. With one finger tap the top edge of an end magnet toward the next adjacent magnet.

Interpretations

5. Describe the results of Procedure H.

<u>Procedures</u> (continued)

I. Focus your attention on the center magnet. Again strike an end magnet as in Procedure H.

Interpretations

6. Describe the behavior of the center magnet.

<u>Procedures</u> (continued)

J. Next set the machine into motion by striking an end magnet at right angles to the length of the machine.

Interpretations

7. Describe the results of Procedure J.

8. In what ways are waves in the two machines similar?

9. In what ways are they different?

Problems

1. Can the S-wave machine transmit P-waves?

INVESTIGATION 10.3: Studying Waves

There are two primary purposes to this investigation: to allow students to become familiar with waves, and to have them notice the differing abilities of the waves to pass through various media.

Verbal descriptions and definitions of waves have shortcomings. They involve both terminology and concepts which are likely to distract students from an understanding of what waves can do. Therefore a minimum of text material is provided for the students, and the amount of accompanying discussion is left to the discretion of the teacher.

The S-wave machine demonstrates shear waves (sometimes called "transverse" waves), and the P-wave machine pressure waves (longitudinal waves). In each machine it is possible to observe the transmission of a pulse of energy through some sort of material. Each type of wave moves through its medium (material) causing a disturbance as it does so. As the wave passes, each paper clip or magnet is disturbed and then returns to its original position. The wave travels, but particles in the medium experience no permanent displacement.

Although the names "S-wave" and "P-wave" are convenient reminders of the natures of these waves, the actual naming resulted from observations of arrival times of the waves at seismographs. Students will read about this in "Earthquakes."

In the case of P-waves each magnet moves in a left-right direction as a wave travels from left to right. The particles are loosely connected to each other, if at all, and hence cannot transmit S-waves. Sound waves in air are of the pressure type. The particles involved are air molecules, which are not firmly connected to adjacent molecules.

In the case of S-waves, the motion of each particle is at right angles to the direction the wave itself is traveling. That is, as the wave travels from left to right the end of each paper clip moves up and down. In order for this to occur there must be a relatively firm connection between adjacent particles.

It is essential that students notice that S-waves are incapable of traveling through the P-wave machine. The observation can be generalized to include all media which lack the firm connection between particles. In short, S-waves can pass only through solids; P-waves can travel through solids, liquids or gases. Be sure that these points have been made in your discussion or summary of the investigation. They will be needed for an understanding of evidence for a core, a topic included in the next reading selection. Openings for such a discussion are provided by Interpretation 7 and Problem 1.

In order to reduce the time required, you may wish half of your teams to construct one type of machine and half the other. Teams can then trade machines.

Materials

One or two pairs of heavy wire-cutters should be available to the class for cutting coat hangers.

Three or four rubber bands, which will form single strands 1/2cm x 18cm when cut, will be needed by each team.

<u>Procedures</u>

A.-D. No comment.

Interpretations

1. Student responses will vary. A wave will pass the length of the machine, "reflect" from the far end and return. In a short time the motion of the paper clips will become confused.

2. Yes, something moved away from the paper clip which was depressed.

3. Student responses will vary. A wave or pulse of energy moves, disturbing each paper clip in turn.

<u>Procedures</u> (continued)

E. The procedure is best observed when the machine is at eye level.

Interpretations

4. As the wave passes the end of the clip moves down and then back to its original position.

<u>Procedures</u> (continued)

F.-H. No comment.

Interpretations

5. Student responses will vary. A pulse moves the length of the machine but probably is not reflected.

<u>Procedures</u> (continued)

I. No comment.

Interpretations

6. As the wave passes the magnet moves first in the direction the wave is moving and then returns to its original position.

<u>Procedures</u> (continued)

J. No comment.

Interpretations

7. This procedure might be expected to generate an S-wave, but the machine cannot transmit this sort of wave.

8. Both waves move through the machines. In each case the individual parts of the machine are not permanently displaced. Students may think of additional similarities.

9. The motion of the magnets is along the direction of the wave motion, whereas that of paper clips is perpendicular to the direction of travel. Speeds of waves in the two machines are different. The S-wave is obviously reflected while the P-wave is not. This last observation is a characteristic of this particular machine and not of P-waves in general. In practice, both types of waves can be reflected.

Problems

1. Yes, P-waves will be transmitted by the S-wave machine. If the rubber band or a paper clip is pulled to one side the far end of the band is disturbed. Thus the S-wave machine can transmit either type of wave (though S-waves are more readily seen), but the P-wave machine can only transmit P-waves.

Students may notice that in a medium through which both types of waves may pass, the rates of travel are different. Thus, while an S-wave takes the better part of a second to travel the length of the rubber strand, a P-wave appears to cover the same distance almost "instantly."

Shortly before midnight on February 29, 1960, a violent earthquake struck the city of Agadir, Morocco. Within minutes most buildings in the city had collapsed and a third of the city's population had died. See Figure 10.12.

On September 1, 1923, the Sagami Bay region of Japan was jolted by one of the most disastrous earthquakes in history. Many buildings were destroyed by the shock itself, others by the 30-foot sea wave which was caused by the earthquake, and still more by fires which broke out in Tokyo and Yokohama. In all, 100,000 people were killed and as many injured.

Fortunately, earthquakes such as these are rare. Many thousands of minor earthquakes occur each year, but on the average there is only one highly destructive one

Figure 10.12. Agadir.

each year. But is it necessary that disasters such as those in Morocco and in Japan occur at all, or can they be prevented?

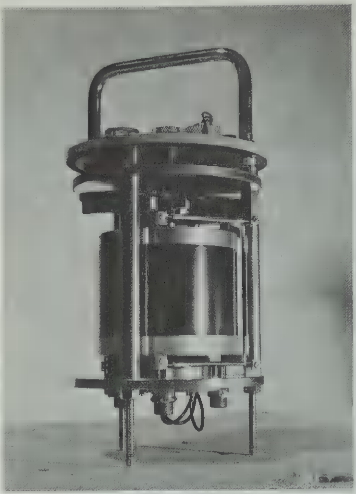
As in most scientific developments, progress begins with a study of history. Historical records indicate areas of the world in which earthquakes have occurred most frequently. In these places special attention must be given to careful selection of building sites and proper construction of buildings. More and better instruments are being developed to measure the exact nature of the shaking that occurs during earthquakes. These in turn will provide still better records for use in the future.

After major earthquakes have occurred, buildings are examined to determine what types of construction have resisted damage and what types are less resistant. Design of buildings changes as more information is gained. Certain types of soils have been found to be particularly dangerous to build on. Intelligent builders avoid such sites.

In current studies attempts are being made to detect increasing strain in the earth before earthquakes actually happen. Through such studies the events preceding earthquakes, as well as those during and following them, are being observed. At present, prediction or prevention of earthquakes seems a long time off. But minimizing of the destructive effects of earthquakes can progress rapidly if people are willing to learn about earthquakes and act upon their knowledge.

Distinct patterns can be recognized in maps showing the areas in which earthquakes are common. These patterns can now be related to large-scale structures of the earth. The locations of active earthquake zones and their significance will be considered in a later section.

In addition to the infrequent, disastrous earthquakes, there are hundreds of thousands of minor earthquakes each year. Many of these can be felt by people and still others



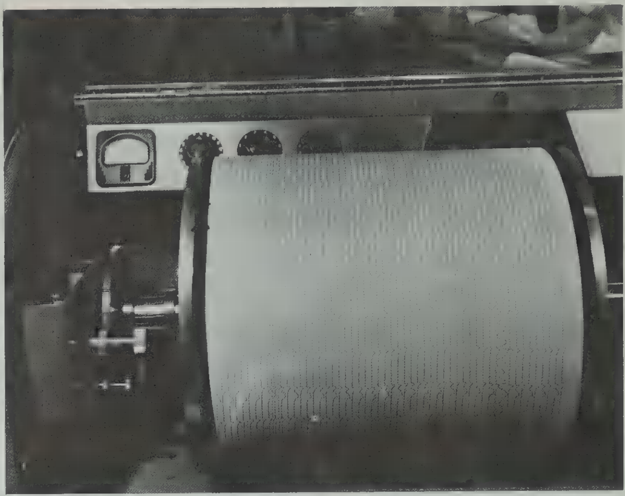


Figure 10.13. Seismograph; left, pick-up; right, recorder.

can be detected only by seismographs, instruments designed for that purpose. From these minor earthquakes information is gained which helps to build a more complete picture of the earth as a whole. See Figure 10.13.

An earthquake occurs when rocks within the earth are strained beyond their breaking points. At the time of the break energy is released in the form of waves and travels away at speeds of five to fifteen kilometers per second. The speeds at which the waves travel depend upon the type of wave, material the wave travels through, and the pressure on the rock, that is, the depth of the rock.

The fastest waves of an earthquake will reach a distant seismograph first. They are called P-waves from the Latin word <u>primus</u>, meaning "first." They are of the type you produced and observed in the P-wave machine of the last investigation. Some time later the seismograph will record the arrival of a second type of wave. These are S-waves (named for the Latin <u>secundus</u>, meaning "second") and are of the type produced in the S-wave machine. The greater the distance from the focus (the earthquake center) to

the seismograph the greater will be the difference in arrival times of the two waves. This difference in arrival times tells the distance from a seismographic station to the focus of the earthquake. Comparison of records from three or more stations establishes the location of the earthquake. Figure 10.14 shows arrival of P- and S-waves as recorded on a seismogram.

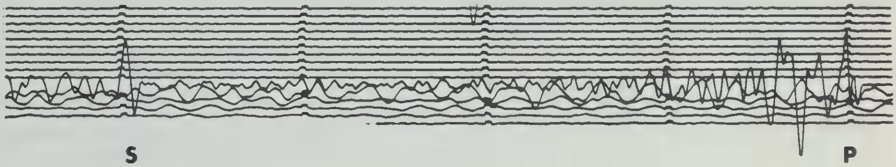
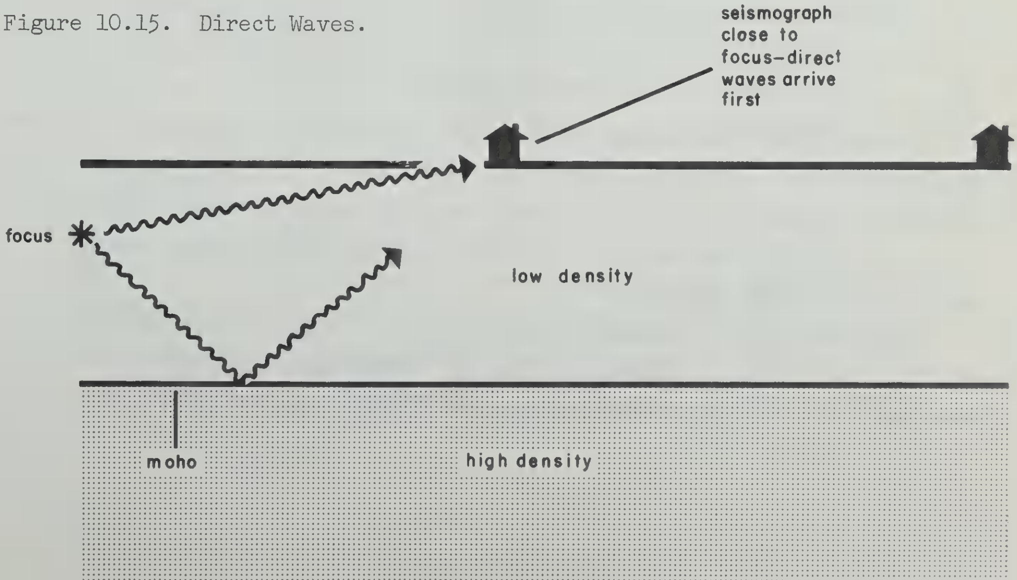


Figure 10.14. Seismogram.

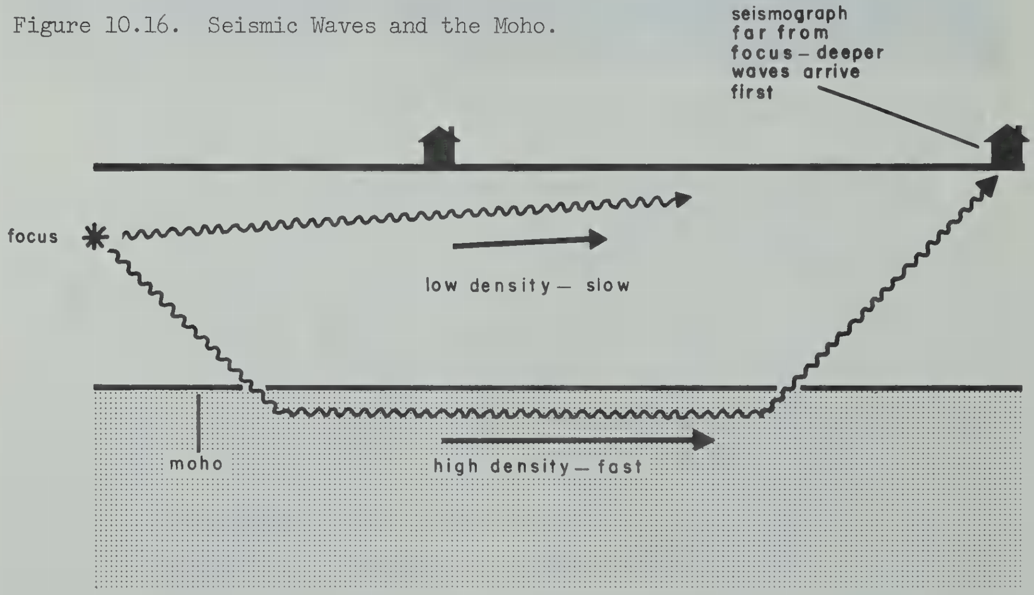
One of the most important conclusions reached through study of seismograph records was made by A. Mohorovicic. He found that at short distances from an earthquake the first P-waves to reach a seismograph were those which had traveled directly from the disturbance to the instrument. See Figure 10.15. Beyond a certain distance, however, the first P-waves to arrive were those which had traveled a deeper path. In passing deeper these waves must have

Figure 10.15. Direct Waves.



reached a material through which their speed was greater. The higher speed more than made up for the greater distance traveled. See Figure 10.16. The increase in speed at depth was not a gradual one, but came quite suddenly suggesting a distinct change from one rock type to another. Mohorovicic calculated the depth of the speed increase, and other investigators have established that the speed increase occurs worldwide. The depth at which the speed increase occurs is now known as the "Moho," short for "Mohorovicic Discontinuity."

Figure 10.16. Seismic Waves and the Moho.



Above the Moho waves travel at speeds which suggest the rocks are primarily granitic, or crust. Below the Moho the higher speeds suggest a more dense rock, similar to gabbro. The deeper part of the earth, beneath the Moho, is known as the "mantle."

Furthermore, the depth of the Moho varies. Its usual depth under the continents is about 32km, but it dips as deep as 64km under mountain ranges. This agrees very

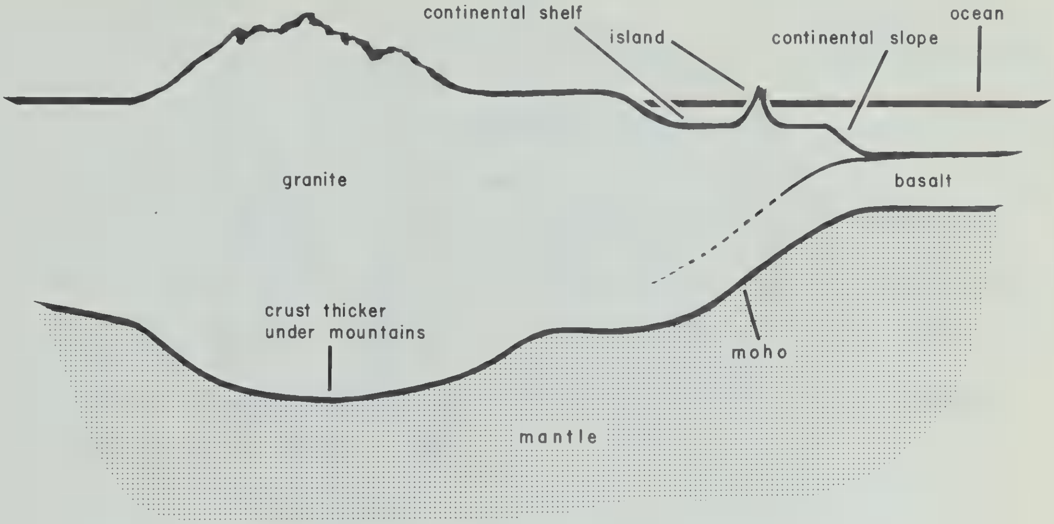


Figure 10.17. Present View of Crust.

nicely with the evidence from plumb bobs which you considered in an earlier investigation. Under the oceans the Moho occurs within 5 or 6km of the surface, and the crust above it is basaltic. Whether the basaltic layer continues under the granitic continents has not been definitely determined. The present view of the crust is represented in Figure 10.17.

Seismographic records of distant earthquakes show that P-waves can travel directly through the earth but that S-waves cannot. In fact, S-waves cannot penetrate deeper than 1800 miles, and at this depth P-waves are markedly refracted. Thus it appears that the earth has a "core." See Figure 10.18.

As better seismographs are developed, as more seismographic stations are set up, and as more records become available for study, knowledge of the structure of the earth will continue to increase.

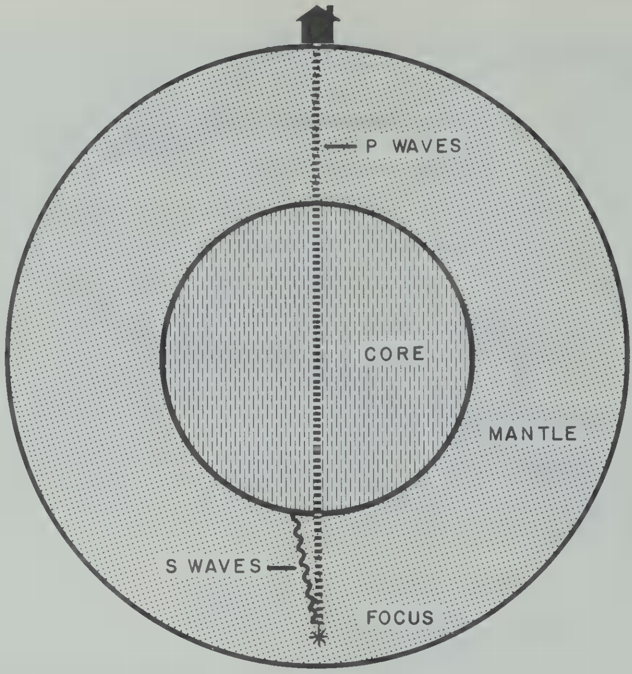


Figure 10.18. Seismic Waves and the Earth's Core.

Problems

1. What does your knowledge of P- and S-waves tell you about the nature of the material of the core?

EARTHQUAKES

As will be brought out in the section on sea-floor spreading, most North American earthquakes center along the West Coast. Notable exceptions, such as the Missouri Valley and Charleston earthquakes, may be of interest to students who live in the areas which were affected by them. Interesting accounts of specific earthquakes may be found in numerous non-technical books on the subject.

Disposal of liquid wastes in deep wells in Colorado has apparently triggered small earthquakes in this area. The implication is that the liquids provided lubrication and relieved stress. This has led to speculation that injection of lubricants into areas of known stress accumulation could relieve the developing stress in small increments. Thus large stress accumulations, which might result in disastrous earthquakes, could be avoided. At present such ideas are still in a speculative stage.

Localization of earthquake foci depends on obtaining data from at least three seismographic stations. A circle is drawn around each station. Each circle's radius is the apparent distance of the disturbance as indicated by differences in arrival times of distinctive waves. The circles drawn around two stations will intersect at two points, indicating two possible foci. The circle around a third station will pass through and identify one of these two points.

An analogy is possible between the discovery of Mohorovicic and driving between two points in a city. Over short distances the best time is made by following the shortest route. Beyond a certain distance, though, a

driver may save time by traveling the greater distance involved in following a highway on which greater speeds are possible.

Of course, waves do not move out from an earthquake focus only along paths which reach seismographic stations (as may be implied by the figures). Waves travel many paths, only those reaching stations being shown in the diagrams.

The argument for existence of a core has been simplified considerably. Travel time curves for different types of waves can be confusing unless considerable time can be allotted to their study. The principle stated is valid, however. Beneath a depth of 1800 miles S-waves encounter a substance they cannot penetrate.

Problems

1. P-waves can travel through solids, liquids and gases. S-waves can pass only through solids. Therefore, the core appears to be non-solid, and most likely liquid.

INVESTIGATION 10.4: Magnetism in Rocks

Information about the structure of the earth comes from a number of different types of observations. Measurements of gravity and recordings of earthquake waves are two of these. Another type of observation is made by studying the magnetic properties of rocks.

Some rocks are strongly magnetic. For thousands of years people have known about lodestones, natural magnets. More recently it has been found that some sedimentary and volcanic rocks are weakly magnetic. At the time these rocks were formed certain minerals in them were lined up parallel to the earth's magnetic field. In a sense this is similar to the way in which a compass needle lines itself up. As the volcanic rocks cooled and the sedimentary rocks hardened, the magnetic minerals within them were "frozen" into position. Study of these rocks can provide information concerning the earth's magnetic field at past times.

Materials (per team)

- Magnetic compass
- Paper cup
- Masking tape
- Ceramic magnet
- Fragment of magnetic "rock"

Procedures

A. Place the compass on your desk top or work table. Remove all metallic and magnetic objects from the area. Decide which is the north-seeking end of the compass needle. This end of the compass needle will be attracted by south poles of other magnets.

B. Use the compass to determine the north and south poles of the ceramic magnet. To identify the poles, write N and S on small pieces of masking tape placed on the magnet.

C. Place the magnet on a blank page in your notebook. The magnet should be positioned so that its north and south poles are to left and right rather than on upper and lower sides. In your notebook, draw lines which show the position of the magnet. Label the north and south poles on the diagram. Draw a rough circle around the magnet at a distance of about 5cm. Place eight dots on the circle, spaced at equal intervals.

D. Place the center of the compass directly over one of the dots. Note the direction of the compass needle. Lift the compass and draw an arrow through the dot on the paper. The head of the arrow should indicate the direction that the north end of the compass needle was pointing. Repeat the procedure with the other seven dots. Notice any patterns formed by the arrows and their relationship to north and south poles of the magnet.

E. While other members of your team look away from the work area, one member of the team should place the ceramic magnet on the work surface in any stable position. No paper need be under the magnet. The paper cup should be placed over the magnet to hide it from view. The team members who originally looked away should now use the compass to determine the location and orientation of the magnet under the cup.

F. If necessary, repeat Procedure E until all members of your team can determine the orientation of a hidden magnet.

G. Obtain a sample of magnetic "rock" from your teacher. Determine the direction of the magnetic field in the "rock."

Interpretations

1. What precautions should be observed in collecting samples of rock for magnetic analysis?

2. What events or processes might change the orientation of the magnetic field within a rock after the rock was formed?

INVESTIGATION 10.4: Magnetism in Rocks

Details for preparation of the magnetic "rock" are not given in the student text. It is suggested that the preparation be done as a demonstration. If the investigation can be scheduled to start on one day and be completed the next, students could perform Procedures A-E and observe preparation of the magnetic material during the first class period. The magnetic "rock" would then harden overnight and be ready for student use on the second day.

Materials

Patching plaster
Plastic or glass container approximately 4" x 4"
Ceramic magnet (to be crushed)
6-8 ceramic, bar or alnico magnets
Hammer or pliers

Preparation of Magnetic "Rock"

Set up a magnetic field by placing bar or other magnets around the container as shown in Figure T-10.4. Be sure that all magnets on one side have the same pole end toward the container, otherwise their fields will cancel and no field will be produced within the container. Ceramic and other magnets of low mass will stay aligned more easily if a nail or other iron object is placed across them on the side <u>away</u> from the container. Magnets are properly aligned when all the magnets in one bank tend to repel each other and magnets of one bank attract those on the opposite side of the container.

Figure T-10.4. Preparation of Magnetic Rock.

Pour about one centimeter of patching plaster, mixed with water to the consistency of sour cream, into the container. The mix should be thick enough to set up properly, yet thin enough so that magnet fragments sink into it slightly.

Place a ceramic magnet in an envelope (or wrap it in paper). Tap with a hammer or crush with pliers to produce fragments 1 to 3cm in length. The fragments will have a tendency to adhere to each other.

Drop small pinches of fragments into the plaster from a height of six to eight inches. If the plaster is of the right consistency the fragments will have sufficient mobility to align themselves in the field but not enough to migrate and clump together. The surface of the plaster should be fairly well covered with fragments.

After about an hour the plaster will have set. The field magnets can be removed and visible magnet fragments covered with plaster from a freshly mixed batch. The entire "rock" should be allowed to harden overnight. It

can then be removed from its container and cracked into sections of 2 to 3cm on a side for distribution to students.

Various problems can be devised by placing the container diagonally across the field, or by tilting the magnets so the field in the rock is not horizontal. You may wish to have the students note the orientation of the "rock" as it is positioned on your desk and then express the relationship of its field to the earth's magnetic field. Notice the comments relating to Interpretation 1.

Procedures

A.-C. No comment.

D. A typical response is shown in Figure T-10.5.

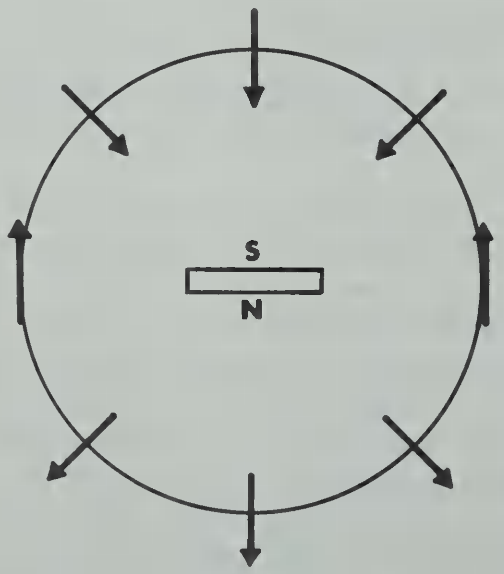


Figure T-10.5. Compass Directions.

E.-G. No comment.

Interpretations

1. Some rocks are inspected in place, in the field, with portable "magnetometers." If a specimen is to be removed to a laboratory the orientation of the specimen relative to the present field of the earth should be noted. Specimens should not be subjected to magnetic or electrical fields which might change their properties. The areas in which specimens are collected should be examined for evidence of crustal movement since formation of the rock.

2. Lightning strikes will change the orientation of magnetic fields within rocks. Rocks may be metamorphosed by younger flows of volcanic rocks.

INVESTIGATION 10.5: Drifting Poles

In Investigation 10.4 you saw how the direction of the earth's magnetic field at some past time might have been recorded in certain rocks and the way in which that direction can now be determined. In this investigation the movement of continents will be used as a model for describing changing locations of the earth's magnetic poles.

Materials (per team)

- Quadrille paper
- Protractor
- Straight edge

Procedures

A. In order to describe directions and locations it will first be necessary to establish reference points and directions. To do this, place a dot on the intersection of two ruled lines near the lower left corner of a sheet of quadrille paper. Label this dot "R." It will serve as a reference point for locations. Vertical lines on the paper will serve as the reference direction from which to measure azimuths. (Review Investigation 1.6 if you do not remember the meaning of the word "azimuth.")

B. Refer to Figure 10.19. In this table the present location of "Continent A" is given as "right 4, up 3." Place a dot labeled A at the intersection which is 4 squares to the right of and 3 squares

up from point R. In similar fashion place dots to represent present locations of "continents" B and C.

Figure 10.19. Chart: Continents.

Time	Continent	Azimuth of North Pole	Location Right	Up
Present	A B C	35° 243° 174°	4 27 13	3 25 36
2	A B C	24° 255° 192°		
3	A B C	9° 264° 216°		
4	A B C	355° 261° 233°		

C. Figure 10.19 also states that the present azimuth of the Magnetic North Pole from A is 35°. Place the protractor with its index mark over point A on your paper. At an angle of 35° measured clockwise from the up direction draw a light pencil line extending out approximately 15cm from point A. Draw similar lines from points B and C using the azimuth given for each in the table.

Interpretations

1. The three lines drawn in Procedure C should form a small triangle near their intersections. Express this location in terms of numbers of squares right and up from R.

<u>Procedures</u> (continued)

D. The numbers in Figure 10.19 labeled "Azimuth of North Pole" and "Time 2" refer to an earlier period of time than the present. Plot these azimuths (lightly) from points A, B and C.

Interpretations

2. Describe the results of Procedure D.

<u>Procedures</u> (continued)

E. It seems likely that the pole has shifted since time 2, but the nature of the shift is not clear. Assume that locations of "Continent A" and "Continent B," represented by points A and B, have not changed but that the location of C may have. Place a dot labeled "C2" (referring to the location of point C at time 2) at location right 15, up 36. From this point draw in the line showing azimuth 192°.

Interpretations

3. Describe the results of Procedure E.

<u>Procedures</u> (continued)

F. On your paper plot azimuths corresponding to time 3 as given in Figure 10.19.

Interpretations

4. What location for the pole at time 3 is indicated by azimuths from points A and B?

5. Does an azimuth of 216° from point C or from point C2 pass through this location?

Procedures (continued)

G. Hold a straight edge on the line of azimuth 216° drawn from point C2. Move the straight edge slowly to the right keeping it parallel to the line of azimuth 216°. Continue to move the straight edge until it passes through the location of the pole at time 3. (This is the point described in Interpretation 4.)

Interpretations

6. What might have been the location of Point C at time 3?

Procedures (continued)

H. Locate the position of the pole at time 4 by plotting azimuths from points A and B. Determine a possible location for Point C at time 4.

Interpretations

7. What might have been the location of Point C at time 4?

8. What assumptions, if any, did you make in determining the location for Point C at time 4?

INVESTIGATION 10.5: Drifting Poles

The techniques of paleomagnetic study reveal the direction of the magnetic pole from different localities in times past. From these studies it appears that the location of the poles is not fixed, but changes. The history of the location of the north magnetic pole as recorded in the rocks of one continent, say North America, conflicts with the history as expressed in the rocks of other continents. The apparent paths of the pole, as perceived from different viewpoints, can be resolved into a single path if it is assumed the continents have been moving relative to each other during the time the pole has moved.

Materials

The quadrille paper should be of the type ruled four squares per inch.

Procedures

A.-C. No comment.

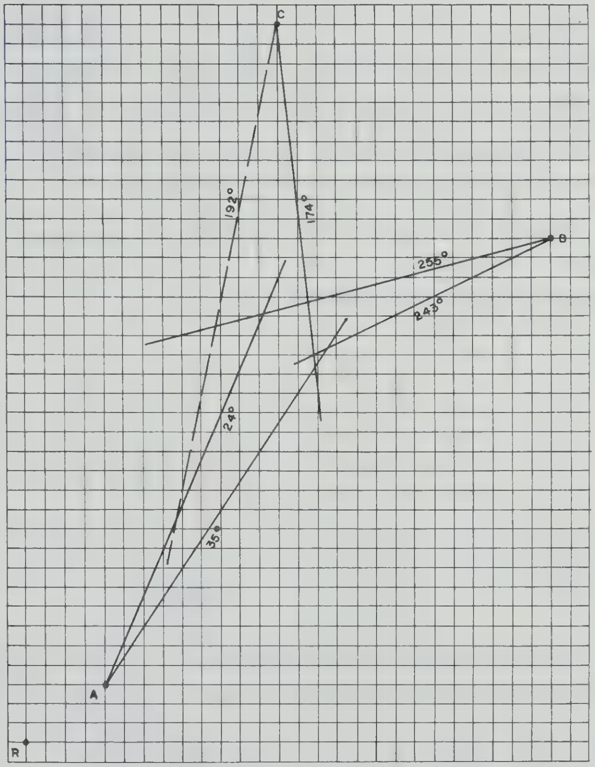
Interpretations

1. The triangle is located at about: right 15, up 19. In using this method the size of the triangle indicates the accuracy of the work, smaller triangles corresponding to smaller amounts of probable error.

Procedures (continued)

D. Figure T-10.6 shows a typical result of this procedure. The solid lines represent the process of Procedures A-D. The dashed line will be changed in Procedure E.

Figure T-10.6. Typical Result.



Interpretations

2. A large triangle is formed. The result is inconclusive. If students do not realize that a problem exists, refer them back to Investigations 3.1 and 3.2.

Sighting to an object from two different locations should establish its position. In this case, "sighting" the pole from A and B gives right 12, up 21 as the location of the pole. Sighting from A and C gives right 8, up 11; and sighting from B and C gives right 10, up 20 or 21. Something must be wrong.

Procedures (continued)

E. Assuming that A and B have remained fixed simplifies the problem. In actuality, only the azimuths (past and present) and the present locations of continents would be known. An entire series of possible former positions of continents would develop. The most acceptable solution would be that which best agreed with other lines of evidence concerning past locations of continents.

Interpretations

3. A small triangle is formed in the vicinity of right 12, up 21.

Procedures (continued)

F. The azimuth from point C may be drawn from location C or from location C2. In neither case will the line intersect the location as determined by azimuths drawn from points A and B.

Interpretations

4. The azimuth lines intersect at R7, U23.

5. No, azimuths of 216° from points C and C2 do not pass through this point.

Procedures (continued)

G. No comment.

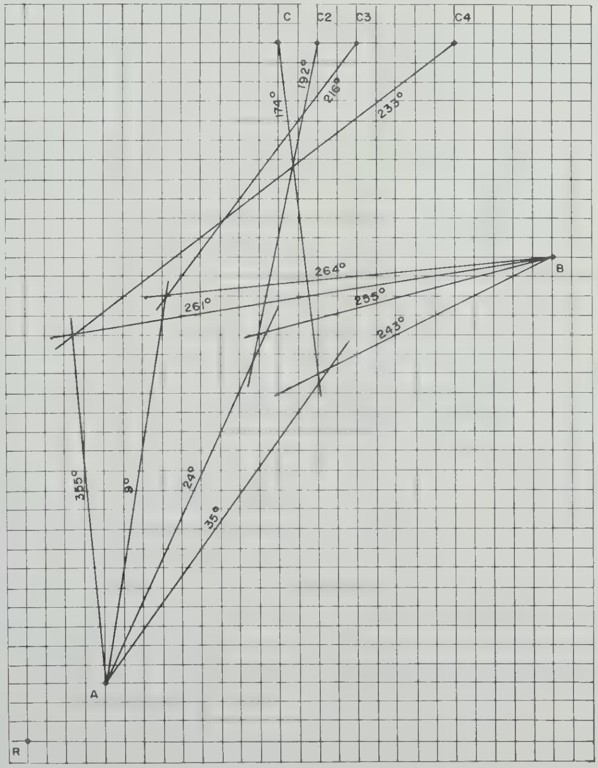
Interpretations

6. Point C may have been located at R17, U36 at time 3.

Procedures (continued)

H. Azimuth lines from points A and B intersect in the vicinity of R2, U21. Procedure G may be repeated to locate point C4. See Figure T-10.7.

Figure T-10.7. Completed Problem.



Interpretations

7. Point C may have been at R22, U36 at time 4.

8. Assumptions were:
   - that points A and B had not moved;
   - that the intersection of azimuths from A and B indicated the proper location for the pole;
   - that C was located somewhere on line U36.

INVESTIGATION 10.6: An Unusual Substance

Various types of evidence suggest that the earth is not rigid at depths of 64 to 250km. Large areas of the earth's surface can apparently move slowly up or down as loads are applied to them or removed. The continents give the appearance of having changed their locations. Such occurrences are not consistent with the idea of a completely rigid material underlying the crust. And yet waves of the shear type can pass through this zone. (From your study of waves you should remember that shear waves cannot pass through fluids.) Some earthquakes even originate in this zone of low rigidity.

Thus the material underlying the crust has some properties which are associated with solids and others which are associated with liquids. Materials with these characteristics are not common, but they do exist. In this investigation you will prepare such a substance.

Materials (per team)

Cornstarch (one rounded tablespoonful)
Water
Shallow dish or saucer
Spoon or nail
Small pieces of metal, plastic and wood

Procedures

A. Place the cornstarch in a dish or other container. Add water, a very little at a time. Stir thoroughly after each addition of water. Continue adding water and stirring until a very thick paste is produced.

Interpretations

1. Describe the appearance of the cornstarch paste.

<u>Procedures</u> (continued)

B. Remove a small amount of the paste from the cup. This material may be handled safely or placed on hard, washable surfaces. Break a small bit of the material and observe the freshly broken surface.

Interpretations

2. Describe the appearance of the freshly broken surface.

3. Describe the appearance of the surface five or ten seconds after it has been broken.

<u>Procedures</u> (continued)

C. Test the paste with small pieces of wood, plastic and metal. Note which substances float and which sink.

Interpretations

4. Which substances float on the paste?

5. Which substances will not float on the paste?

<u>Procedures</u> (continued)

D. Attempt to slide a floating object over the top of the paste, first slowly and then rapidly.

Interpretations

6. Can a floating object be moved slowly over the cornstarch paste without disturbing the surface?

7. What happens when the object is pushed rapidly?

8. In what ways does the paste resemble a liquid?

9. In what ways does the paste resemble a solid?

10. Do you think shear waves could pass through cornstarch paste?

TEACHER MATERIAL

INVESTIGATION 10.6: An Unusual Substance

Substances are often thought of as being either solid, liquid or gaseous. The dividing line between solids and liquids, at least, is not clear cut. A number of materials, cornstarch paste and paraffin among them, will exhibit some of the properties usually associated with solids and some of those associated with liquids. Such materials are rigid enough to pass shear waves or even to break, if stresses are sufficiently high, but will flow if given time. It is hoped that students who have observed this association of properties in cornstarch paste will be able to imagine similar properties in rock under great pressure.

Materials

Kingsford's brand cornstarch is suitable for use in this investigation. It is available in most markets. A one pound package contains more than 30 rounded tablespoonsful.

Shallow dishes are better than cups for observing the paste, but practically any container will do. If necessary the paste can be mixed in plastic or paper cups.

Any washable or disposable objects, such as coins, keys or erasers, may be tested.

The spoons should be of metal or of sturdy plastic. Iron nails may be substituted for stirring rods. Glass stirring rods should not be used.

Procedures

A. Approximately two tablespoonsful of water will make a mix of correct consistency when added to one rounded tablespoonful of powdered starch.

Interpretations

1. The undisturbed paste presents a glossy appearance such as is usually associated with liquids.

Procedures (continued)

B. No comment.

Interpretations

2. A freshly broken surface has a grainy appearance.

3. The surface quickly resumes a smooth, glossy appearance.

Procedures (continued)

C. No comment.

Interpretations

4. Responses will vary according to the materials tested.

5. Responses will vary.

Procedures (continued)

D. No comment.

Interpretations

6. Yes, a floating object can be moved slowly without breaking the surface of the paste.

7. If the same floating object is pushed rapidly the paste "breaks."

8. The paste resembles a liquid with its glossy surface, ability to flow, and ability to support floating objects.

9. Pieces of the paste will remain rigid for short times and will break in a manner suggesting solids.

10. Student responses will vary. The paste probably would transmit shear waves. Encourage experimentation on this point. A long, thin bar of paste might be laid out on the work surface. Quick, sideways forces applied to this bar will be transmitted through its length.

SEA-FLOOR SPREADING

The geology of ocean floors is quite different from that of continents. You are already familiar with the difference in composition between types of rocks which are typical of the two. Most rocks of the continents are granitic, those of the ocean basins basaltic. What other differences exist?

The ages of older continental rocks must be expressed in hundreds of millions of years. The very oldest rocks are known to be several billion years old. By contrast, the oldest sedimentary rocks from ocean floors seem to be only 150 million years old. Most are only half that age, or less. At the time the oldest ocean bottom sediments were being deposited there were dinosaurs on the land, coal beds had been deposited, and successions of mountain ranges had long since risen and been eroded away. Perhaps the search of ocean floors has not been thorough enough. However, there is other evidence for believing the ocean floors are relatively young.

Much of the Atlantic Ocean floor lies beneath 4,000 to 6,000 meters of sea water. But near the center of the Atlantic lies a nearly continuous range of mountains, the Mid-Atlantic Ridge. At points along the ridge, mountain tops project above the surface forming islands: Surtsey, the Azores, Ascension, and others. Throughout much of its length the ridge rises one or two thousand meters above the floor and is several hundred kilometers wide.

Just by itself the Mid-Atlantic Ridge would stand as one of the major geologic features of the earth. However, it is but one branch of a continuous range of undersea mountains 60,000 kilometers long. By comparison, the mountain ranges of the continents seem short and insignificant. What else about the Mid-Atlantic Ridge is remarkable?

For one thing, its course follows a winding path, remaining almost equally distant from the continents to the east and west of it. The ridge is offset by numerous faults, fractures in the crust, which are perpendicular to the trend of the ridge.

Along the crest of the ridge runs a "rift" valley. This valley gives the appearance of having been formed by tension, as if the sides of the range had been pulled apart and the center of the ridge had collapsed. See Figure 10.20.

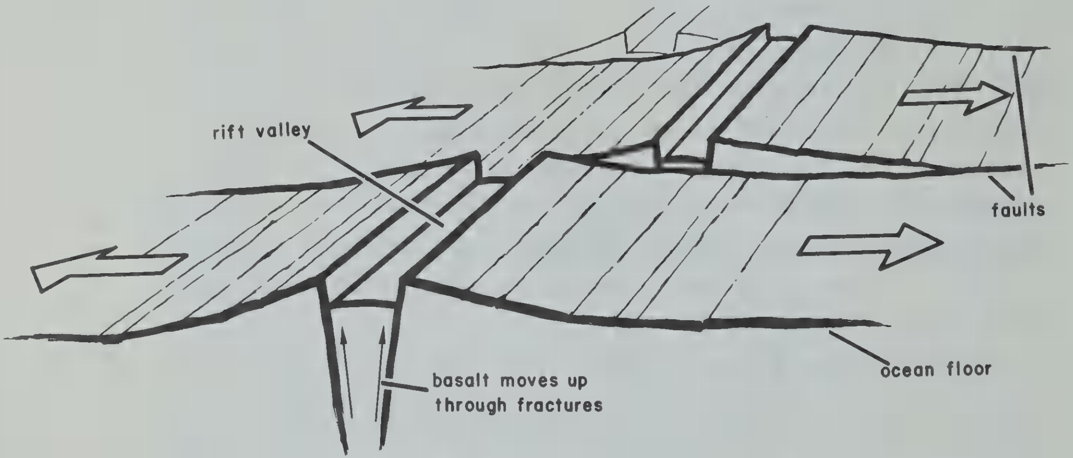


Figure 10.20. Ridge and Rift Valley.

The ridge is composed of flows of basaltic rock which have been erupted from near the central rift of the ridge. The flows lie in symmetrical pairs of bands which parallel the crest of the ridge. The youngest flows lie close to the crest of the ridge and the oldest ones farthest from the ridge. Matching pairs of these flows show similar magnetic properties. See Figure 10.21.

As you now know, the direction of the earth's magnetic field can be frozen into a rock at the time the rock is formed. One of the most surprising things which has been

learned from the study of magnetism in ancient rocks is that the direction of the earth's magnetic field occasionally reverses direction.

The changes in direction of the earth's magnetic field have occurred nearly 200 times since the latter part of the Mesozoic Era. As shown in the magnetic fields of the rocks, the earth's field has remained in its "normal" direction (the direction it now points) for up to two or three million years. Then it changes to a "reversed"

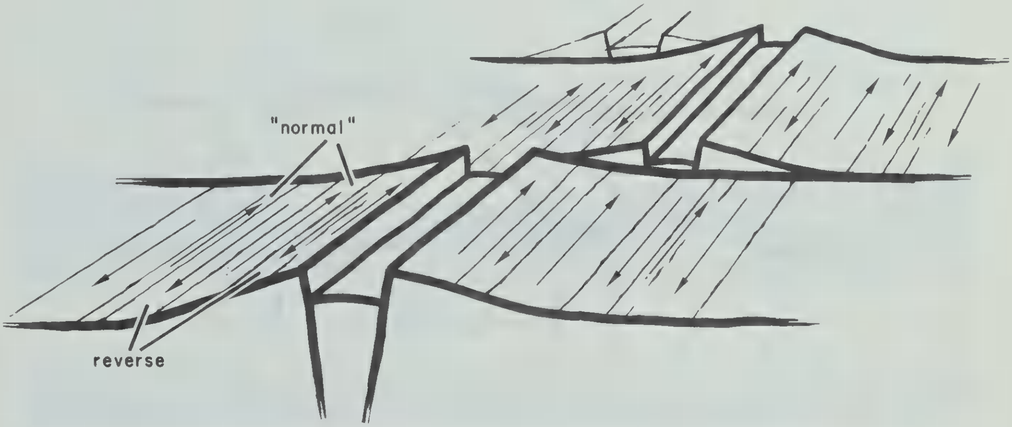


Figure 10.21. Normal and Reverse Magnetic Fields.

direction. The change from normal to reversed field takes place in relatively little time. During a period of reversed field compass needles would point away from the north magnetic pole.

The entire structure of the Atlantic Ocean is consistent with the idea of eastern and western parts of the sea floor being pulled away from each other. As this occurs the central part of the ridge collapses to produce the rift. Basaltic lava rises up through cracks which are caused by the tension and builds up the ridge itself.

Faults which are perpendicular to the ridge result from spreading occurring at different times or at different rates along the ridge.

Comparing the patterns of magnetic reversal in bands of basalt makes it possible to identify flows which occurred at the same time and then were separated by the spreading. Measurements of the ages of these bands and the distances between them show that spreading goes on at 1 to 10cm per year. See Figure 10.22.

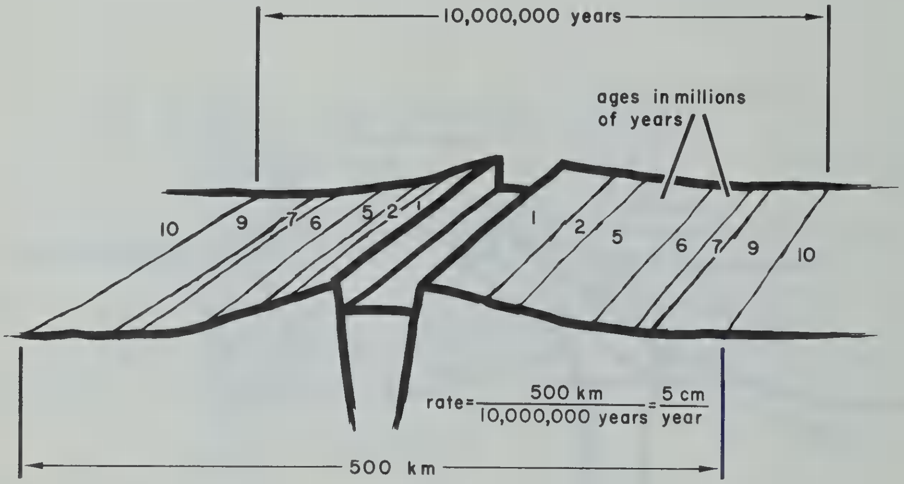


Figure 10.22. Rate of Spreading.

If the spreading has gone on at a fairly regular rate (and it appears to have done so), the Atlantic Ocean is only about 150 million years old. This would account for the absence of rocks of greater age than that.

The Mid-Atlantic Ridge and other ocean ridges seem to mark the trailing edges of about ten large "plates." A plate is roughly the size of a continent. It includes crust, both continenal and sea floor, and a certain amount of the underlying mantle rock. Beneath the plates, at a depth of about 64 to 250 kilometers, the mantle rock is

apparently less rigid. This lack of rigidity is suggested by the observation that earthquake waves travel more slowly at this depth than they do at greater or lesser depths. As a plate moves horizontally more material is added to its trailing edge by basalt flows from the ocean ridges. See Figure 10.23.

What occurs at the leading edge of a plate? Three possible situations will be mentioned.

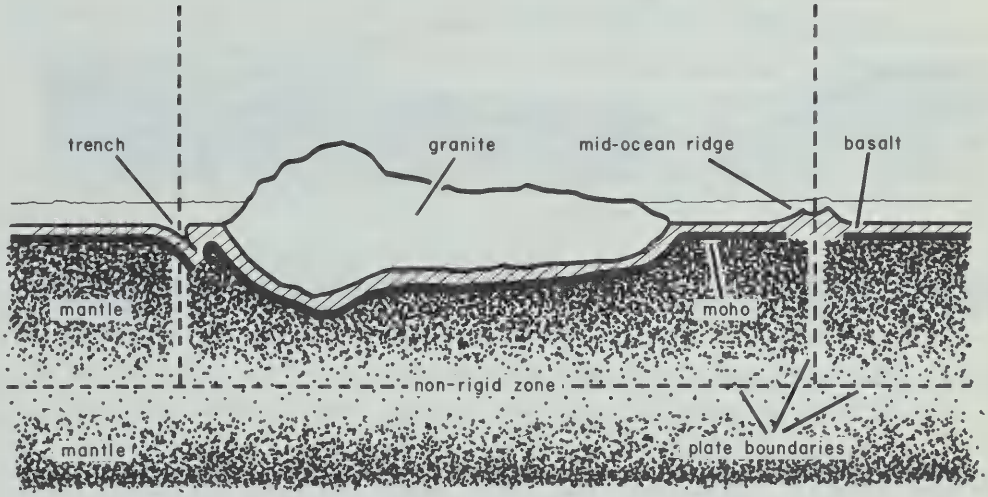


Figure 10.23. A Plate.

Along the western (leading) edge of the South American plate is a deep trench in the sea floor. The trench is 1900km long and its bottom is 8000m beneath sea level. This makes the water over it more than twice as deep as the average depth of the Pacific Ocean. Extending downward and to the east from the trench is a fault zone. Along this zone crustal material is plunging downward into the mantle, as shown in Figure 10.24. The denser parts of the crust are probably being melted into more mantle rock. The less dense rock tends to "float," and in doing so adds

extra thickness (the Andes Mountains) to the granitic crust. It is hardly surprising that with such events in progress the western edge of South America has numerous volcanoes and frequently experiences earthquakes.

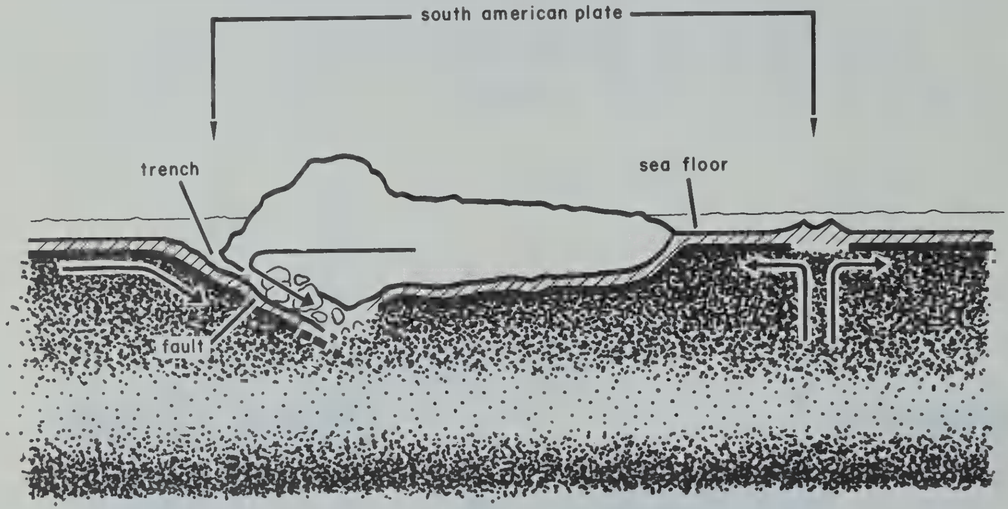


Figure 10.24. Movement of the South American Plate.

A somewhat different situation occurs along the western edge of North America. The North American plate has already ridden over a trench similar to the trench west of South America. The next plate to the west is moving north relative to the North American plate. The boundary between the two is represented by the San Andreas Fault. This fault separates Baja California from Mexico and parts of the California Coast from the bulk of the North American plate. As in the case of South America, a zone of mountain ranges, volcanoes, and of frequent earthquakes marks the leading edge of the plate.

Figure 10.25 shows the Mid-Atlantic Ridge at the trailing edges of the American plates. Trenches are shown as dotted lines, and earthquake locations as small dots.

The third example to be mentioned is that of India. The plate which includes India moves north and is in collision with the plate of continental Asia. The line of collision is marked by the great Himalayan mountain range. The Indian plate seems to be "diving under" the Asian plate, resulting in a crust of more than normal thickness.

Using the various lines of evidence you have considered, the paths of the plates can be projected back in time. At the beginning of the Mesozoic Era all continents appear to have been assembled in one or two "supercontinents." Shortly thereafter the breaking-up process began, and the continents have since moved to their present locations.

It can be expected that details of the movements of the plates will be worked out as more observations are made. Some major problems must yet be solved. One of these is the nature and origin of forces large enough to be moving the plates. Assuming that this problem is resolved, there will still be more work to do. The break-up of the "supercontinent" appears to have begun only after 95% of the time since formation of the earth had gone past. Did the continents move during the greater part of Earth history? What dimly preserved evidence will lead to tracing their paths?

Figure 10.25.
The American Plates and the Mid-Atlantic Ridge.

FOR FURTHER ACTIVITY

Prepare a scale diagram showing the structure of part of the earth. In the sketch use a scale of 1mm to represent 1km. Start by drawing a horizontal line to represent sea level.

Since the average height of the North American land surface is less than 1km above sea level, you should represent it with an irregular horizontal line less than 1mm above the sea level line. The Moho lies at a depth of about 32km. It should be represented by a line 32mm beneath the surface. The summit of the highest mountain in North America, Mt. McKinley, is 6km above sea level. This height in the sketch should be 6mm.

Working to the same scale, represent the depth of the Moho under mountains (64km), the average depth of oceans (4km), the depth of an ocean trench (8km), the non-rigid zone, the boundary between mantle and core, the width of a plate, and other large-scale features of the earth.

Problems

1. Why do you think that diagrams showing the structure of the earth are not always drawn to scale?

2. Near the end of Section Nine it was stated that India showed signs of having been glaciated during the Permian period. How might the idea of drifting continents account for the fact that India was glaciated but that its surroundings were not?

FOR FURTHER ACTIVITY

Students who attempt this activity may be surprised by the fact that their sketches, even to this scale (1,000,000 to 1), soon run off the page. You may wish to have students prepare a classroom sketch on butcher paper. This sketch would show the surface-to-center distance of 6400km as 6.4m. The core-mantle boundary would occur at a depth of 2.9m. The non-rigid zone would appear at depths ranging from 64 to 250mm. The width of a plate, from mid Atlantic to West Coast would be about 5.5 to 6m. Students could then place their detailed surface diagrams against the classroom sketch in order to gain some idea of the perspective of the features they have been considering.

Problems

1. If a sketch were made to scale and of such a size that the width of a plate could be represented on a page, the crust would be compressed into a band a few millimeters thick, and detail would be lost.

2. Current thinking suggests that Antarctica has occupied its present location at least since Permian time. At that time India (as well as Africa and South America) were contiguous to Antarctica. Since then, each has drifted to its present location. Thus India was not surrounded by its present neighbors at the time of the glaciation.

THE FUTURE OF DRIFT

Some of the models which you have developed while using this book are not likely to change greatly. As an example, the earth-sun model of Sections One and Two has been in use for several hundred years. During this time it has occasionally needed minor adjustments to make it agree with new observations, but the major features of the model have not changed. The model has been so useful in explaining so many observations that it is difficult to think of the solar system without thinking of this model. Its widespread acceptance should be based only on its usefulness and not partly on the fact that it has been in existence for many years and has been written about in many books. No model should ever become so deeply rooted that no one bothers to look at it critically.

On the other hand, some models which you have studied are almost certain to change. The idea of continental drift is one of these. During the next few years you can expect to see many newspaper and magazine articles about the subject. Different rates of drift, different paths for the continents, different starting positions, new evidence supporting drift, new problems concerning energy sources . . . all these and others will appear.

Magazines and newspapers can be printed and distributed rapidly. For this reason they are better sources of information about late developments along the frontiers of earth science than are textbooks. Textbooks have their place. From them you can find out what problems exist and learn the histories of attempts to solve the problems. With the addition of up-to-the-minute information from periodicals you will be able to follow the growth and development of knowledge, of models, and of science itself.

Section Eleven:

Earth, Sea and Air

PREVIEW

The various disciplines that make up earth science are not separate and distinct entities. The purpose of this short section is to provide students with opportunities for recognizing overlaps and interrelationships between the disciplines.

Using climate as a unifying thread, it is shown that the phenomena that have been studied form an intricate mesh of interactions. These interactions have produced the earth they now view and will continue to produce change in the future.

Throughout the section encourage students to look for such relationships, not only of climate and geology or of climate and paleontology, but also of landscape and paleontology, of weather and earth-sun relationships, and others.

Insofar as climate itself is concerned, the principles which are brought out here are generally illustrated by examples which are not taken from North America. Work with the students in developing a recognition of what their local climate is and the factors which influence it.

A reading selection draws to the students' attention the fact that boundaries may be indistinct. This is followed by a discussion and problem set dealing with averages.

In Section Three students investigated the effect of a tilted earth on the length of daylight in different latitudes, and in Section Six the length of day was related to ocean temperatures. A further reason for the relationship between latitude and temperature is shown in Investigation 11.1, in which angle of incidence is studied.

Investigation 11.2 (Heat Balance) pursues the idea that--over a period of time--heat added to the earth equals heat lost by it, but that local and temporary changes in total energy account for variations in temperature.

In Sections Six and Eight it was suggested that global water and air circulation patterns were affected by rotation of the earth. The basis for the effect is taken up in Investigation 11.3. This investigation also provides evidence for rotation of the earth on its axis, a fact that was simply assumed in the early parts of the course.

Landscape and Climate, a reading selection, suggests relationships between the topics considered in Sections Nine and Ten and the distribution of climates on the earth.

The effect of oceans on climate, hinted in Sections Six and Eight, is described in Oceans and Climate.

The section concludes with a discussion of the continuing nature of change on earth, a concept suggested by various evidence presented throughout the course.

Section Eleven:

Earth, Sea and Air

CROSSING BOUNDARIES

Some boundaries are very sharply drawn. There are places where a person can stand with both feet in the United States, take a single step, and be completely in Canada. Other boundaries are less distinct.

Florida is noted for its mild winters. In the Yukon Territory, winters tend to be quite cold. There is no sharp line dividing areas of mild winters from those of cold winters.

A person who was interested in describing winter conditions in different regions might decide to simplify matters. Instead of trying to draw a sharp line between cold and mild regions he might set up a new classification, a zone in which winters are "moderate." Then there would be no need for a line separating cold from mild. The original problem would be solved, but there would be two new ones to take its place. Where should the boundaries be drawn between cold and moderate, between moderate and mild? Perhaps you can see that the problem has no complete solution. There is no limit to the number of boundary lines which might be drawn, each requiring a new decision as to location.

The fact that distinct boundaries cannot be drawn should not be taken to mean that there are no differences between two areas. The problem arises only if someone attempts to draw a sharp boundary where one cannot be drawn.

What about different areas of science? Are there distinct boundaries between them? At first there may seem to be. What could be more different than biology, a study of living things, and geology, the study of rocks? But some rocks, such as limestone and coal, are the result of biological processes and some trees grow only in soils derived from specific types of rock.

In this course you have considered various areas of earth science. Perhaps you have noticed that the boundaries between areas of study were not sharply drawn, that there were overlaps between them. The study of astronomy overlaps the study of geology. Studies of weather and of fossils overlap.

New names have been applied to areas in which it was difficult to find distinct boundaries. Geophysics is a term used to describe the area in which the boundary between geology and physics (the study of waves, forces, etc.) is not sharp.

In this section you will consider a new topic, climate. An attempt will be made to show that this topic is really not separate and distinct from other subjects you have considered. You may find it interesting to look for relationships between each of the topics of this course. Perhaps by doing so you will recognize some of the relationships and interactions between things and processes which are normally considered distinct areas of study.

TEACHER MATERIAL

CROSSING BOUNDARIES

The various disciplines that make up earth science are not separate and distinct entities. The purpose of this short section is to provide students with opportunities for recognizing overlaps and interrelationships between the disciplines.

Using climate as a unifying thread, it is shown that the phenomena that have been studied form an intricate mesh of interactions. These interactions have produced the earth they now view and will continue to produce change in the future.

Throughout the section encourage students to look for such relationships, not only of climate and geology or of climate and paleontology, but also of landscape and paleontology, of weather and earth-sun relationships, and others.

Insofar as climate itself is concerned, the principles which are brought out here are generally illustrated by examples which are not taken from North America. Work with the students in developing a recognition of what their local climate is and the factors which influence it.

AVERAGES

Climate is sometimes defined as the "average" weather for some particular place. This is a useful definition, but you should be aware of some of the problems involved in using averages.

St. Louis, Missouri, and "City Q" both have the same average year-round temperature, 12.6°C. In each case the yearly average has been found by adding up average daily temperatures throughout the year and dividing by the number of days in a year. Perhaps you can see how two entirely different patterns of temperatures could both result in the same average temperature.

The difference between temperatures during the hottest and coldest months in St. Louis is 26°C. In City Q the difference is only .4°C. Thus the averages alone do not give an accurate idea of temperatures to be expected. Numbers such as .4°C and 26°C are known as "ranges." They are often given when averages are stated and are very useful in helping to understand what the average means.

Problems

1. An observer measures the wind speed each afternoon at the same time for 30 days. He then adds the daily readings and divides the total by 30. He finds an average wind speed of 10mph. Describe two sets of observations, representing very different conditions, which might have led to the 10mph average.

2. What "range" of wind speeds would be associated with each set of observations you described for Problem 1?

TEACHER
MATERIAL

AVERAGES

Encourage speculation about the location of "City Q." (Actually, City Q is Quito, Ecuador, located at less than 1° south latitude and at 9300 feet elevation.) Following their work on the effect of the angle of incidence, students will be asked what effect latitude might have on the climate of City Q. Following "Landscape and Climate," students will be asked how altitude might contribute to the small range of temperatures.

Throughout this section, temperature ranges are given as differences between average temperatures for the warmest and coldest months. You may wish to ask students what the effect would be of expressing the ranges in terms of difference between warmest and coldest days of the year. If they have understood the selection about averages, they should recognize that such a manner of expressing ranges would result in the ranges being greater than the ranges between average temperatures of hottest and coldest months.

The hottest day in the warmest month is certain to have a higher temperature than the average for the month. The coldest day of the coldest month will similarly be colder than the average temperature for that month. Thus the range between warmest day and coldest day will be greater than the range between average temperature of the warmest month and average temperature of the coldest month.

Problems

1. A variety of responses is possible. The greater the number of situations which can be described, the greater will be the emphasis on the inability of averages to tell the entire story. Extreme cases would be:

a. Zero mph measured on 29 days and a speed of 300mph measured for the other day. This highly improbable situation might occur if a tornado struck.

b. Ten mph measured on each of the 30 days. Again, this situation is improbable, but might be approached in some areas.

2. In case a, above, the range would be 300mph. In case b, above, the range would be zero mph.

INVESTIGATION 11.1: Angle of Incidence

In your study of astronomy you used a light meter to investigate effects of increasing distance between meter and light source, and of changing brightness of source. Now you will use the same meter to help you understand the effect of the angle at which light strikes a surface. This angle is known as the "angle of incidence."

Materials (per team)

- Light meter
- Light source
- Ruler
- Protractor
- Masking tape

Procedures

A. Use the protractor and ruler to duplicate Figure 11.1 on a sheet of paper.

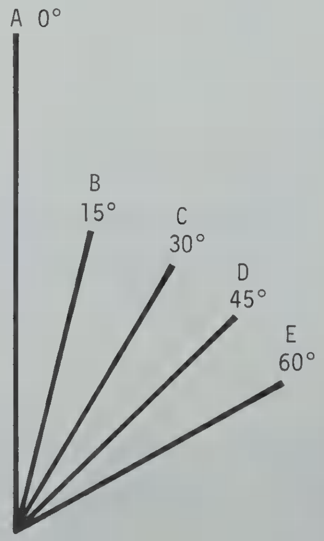


Figure 11.1. Angles of Incidence.

B. Place the paper on your work surface and the light meter on the paper. A long edge of the meter should be lined up with line A on the diagram.

C. Rotate the paper, with the meter on it, until the meter is pointing directly at the light source. Tape the paper to your work surface. Read the meter and record your measurement in a chart similar to Figure 11.2 in your notebook.

Figure 11.2. Chart.

LINE	ANGLE OF INCIDENCE	METER READING
A	0°	
B	15°	
C	30°	
D	45°	
E	60°	

D. Adjust the meter so that its edge is lined up with lines B, C, and E in turn, but not with D. At each position, read the meter and record the reading.

Interpretations

1. What is the effect on the meter readings of increasing the angle of incidence of the light?

2. Predict what you think will be the meter reading with an angle of incidence of 45°.

Procedures (continued)

E. Align the meter with line D. Record the meter reading.

Interpretations

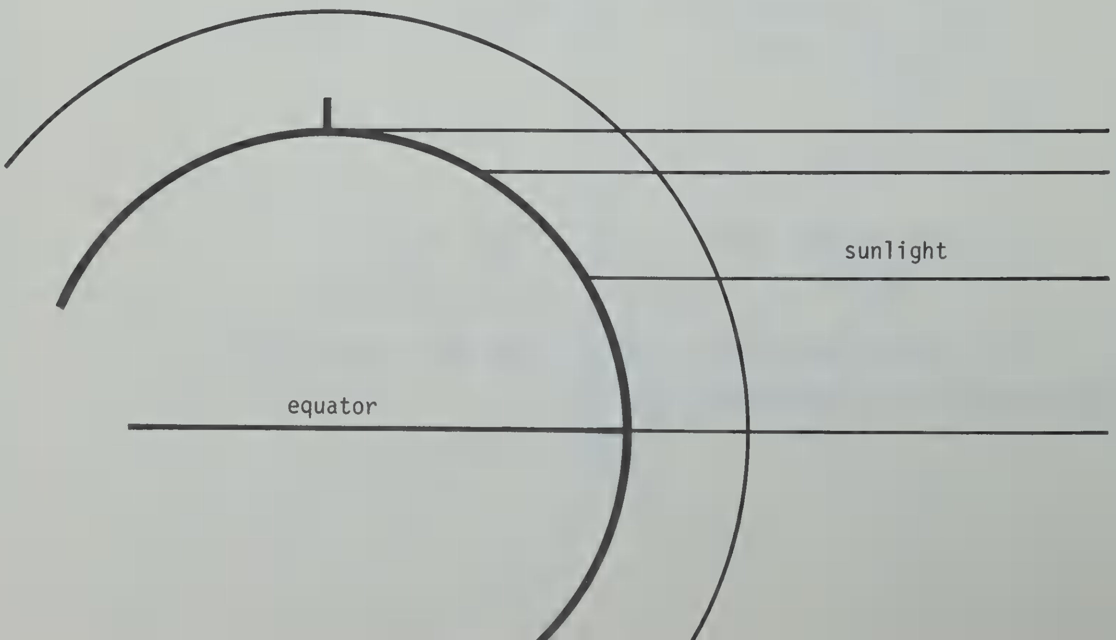
3. Was your prediction of Interpretation 2 accurate?

4. How do you account for the readings you have obtained?

Procedures (continued)

F. Look at Figure 11.3. The inner circle in this figure represents the surface of the earth. The outer circle represents the "top" of the atmosphere. The parallel lines represent rays of the sun striking the earth at latitudes 0°, 30°, 60°, and 90°.

Figure 11.3. Apparent Thickness of Atmosphere.



Interpretations

5. What time of year does the diagram represent?

6. At what latitude is the angle of incidence greatest?

7. At what latitude is the angle of incidence least?

Procedures (continued)

G. Use a ruler to measure the distances each ray travels in passing through the atmosphere. Record these measurements in your notebook.

Interpretations

8. Do you think the heating effect of the sun is greatest when the angle of incidence is small or large? Explain your answer.

9. On a year-round basis, what parts of the earth's surface receive the most incoming sunlight? The least?

10. Does the seasonal change in tilt of the earth's axis result in a greater seasonal difference in heating at low or at high latitudes?

Problems

1. Based on its temperature range only, what do you think City Q's latitude may be? (Hint: Examine your response to Interpretation 10.)

2. How does latitude affect the climate of the place where you live?

TEACHER MATERIAL

INVESTIGATION 11.1: Angle of Incidence

By convention, the angle of incidence is measured from the perpendicular (or "normal" line) to the incoming ray, and not from the surface to the incoming ray. Thus a ray which strikes a surface at right angles is said to have a 0° angle of incidence. The purpose of the investigation is to show the effect of latitude on the climate of a place.

Procedures

A.-B. No comment.

C. The effects to be observed will be most easily seen if the room is partially darkened.

Students may align the meter exactly with the 0° line (line A) by observing the shadow of the meter or by adjusting for a maximum reading of the meter. The investigation will work best if the light source is located close enough to the work areas to cause at least half-scale deflections of the meter at 0° incidence.

D. No comment.

Interpretations

1. As the angle of incidence is increased, the meter readings decrease.

2. Student responses will vary.

Procedures (continued)

E. No comment.

Interpretations

3. Student responses will vary.

4. Two major reasons may be suggested:

As the angle of incidence is increased the amount of reflection from a surface (here the photocell) is also increased. Less light will be absorbed and recorded by the meter.

As the angle of incidence increases a smaller percentage of the light output of the source will strike the meter. This is illustrated in Figure T-11.1. If the meter is turned from its solid line position to the dotted line position the portion of the light between B' and B will no longer fall on the meter.

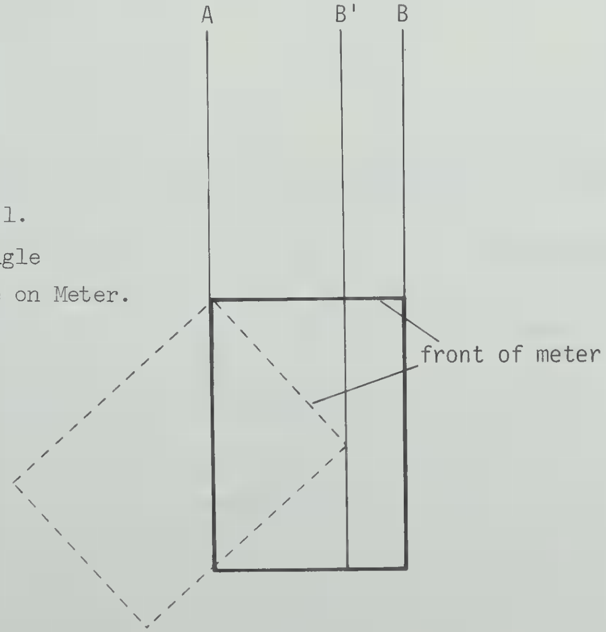


Figure T-11.1. Effect of Angle of Incidence on Meter.

A typical set of readings would be:

LINE	ANGLE OF INCIDENCE	METER READING
A	0°	.24
B	15°	.23
C	30°	.20
D	45°	(.18)
E	60°	.12

Procedures (continued)

F. The thickness of the atmosphere is exaggerated.

Interpretations

5. The diagram represents an equinox. This can be concluded from the fact that rays of light from the sun are perpendicular to the rotational axis of the earth. See Investigation 1.5.

6. The angle of incidence is greatest at 90° latitude.

7. The angle of incidence is least at 0° latitude.

Procedures (continued)

G. Typical values are:

Latitude	Distance
0	1.9cm
30	2.1cm
60	2.8cm
90	4.9cm

Interpretations

8. The heating effect is greatest when the angle of incidence is small. In addition to the two reasons suggested for Interpretation 4, students may add:

The sun's rays pass through a lesser amount of air.

Low angles of incidence correspond to summer with its longer days.

9. The regions close to the equator receive the most incoming sunlight and those near the poles the least.

10. The change in tilt causes relatively little change at low latitudes. Students may notice that the difference in distance through the atmosphere (Procedure G) changes only slightly between 0° and 30°, more between 30° and 60° and most in the polar region.

Also, the decrease in light-meter readings was least between 0° and 15° and larger when greater angles of incidence were involved.

Problems

1. The small temperature range of City Q suggests an even amount of energy being received. This corresponds to a location near the equator. Students may wonder why, if the city is near the equator, its average temperature is not higher. This will be considered at a later time.

2. Student responses will vary.

INVESTIGATION 11.2: Heat Balance

Each place on the earth is continually losing heat to space, day and night. During the day the heat is replaced by radiation from the sun. Any difference between heat gained and heat lost causes a change in temperature for the place. This investigation may help you to understand why some temperature changes follow the patterns they do.

Materials (per team)

Paper cup
2 beakers
Masking tape
Ruler
Water

Procedures

A. Place marks at 2mm intervals along one edge of a piece of masking tape for a distance of 6cm. Attach the tape to the inner surface of a paper cup from bottom to top. Use a sharp pencil or other pointed object to make a small hole in the side of the cup just above its bottom. The hole should be the right size to allow most of the water to drain out of a full cup in about one minute.

B. Place the cup where water draining from it will empty into a sink or beaker. Add water to the cup from a second beaker until the depth of the water in the cup is about 5cm. Continue to add water at a rate which keeps the water level constant, then decrease the rate at which water is being added to the cup.

Interpretations

1. Is it possible for the water level in the cup to drop while water is being added to the cup?

2. If so, under what conditions will this happen?

3. Do you think it would be possible for the temperature of a place on earth to decrease while heat from the sun was still being added to it?

4. If so, under what conditions would this occur?

<u>Procedures</u> (continued)

C. Add water to the cup at a rate which maintains the level of water in the cup at a depth of about 1cm. Next add water at a high rate, and then gradually decrease the rate at which water is being added. Carefully observe any changes in water level which occur after you start to decrease the rate at which water is being added.

The sun adds more heat to the northern hemisphere on the day of the summer solstice in late June than on any other day. Both before and after this date heat is added at a lower rate. And yet this day does not usually have the highest temperature of the year. Records from a large number of locations in North America show that the warmest days of the year occur during July and August.

Interpretations

5. How can you account for the temperature pattern described in the paragraph above?

The northern hemisphere receives its smallest amount of heat on or about December 21. After that date heat is added in increasing amounts. And yet records show that the coldest days in many places occur in January and February.

FOR FURTHER ACTIVITY

Design and carry out an investigation which would illustrate possible reasons for the occurrence of coldest days of the year in January.

INVESTIGATION 11.2: Heat Balance

In this investigation students will construct a physical analog for the heat balance of the northern hemisphere.

Materials

Six-ounce cold drink cups are satisfactory.

If sinks are available, each team will require only one beaker.

Procedures

A. The pencil marks on tape will serve as indices to help in detecting changes in water level.

B. No comment.

Interpretations

1. It is possible for the water level to drop while water is being added.

2. This will occur if water is draining from the cup at a greater rate than it is being added.

3. Yes, it is possible for the temperature of a place to drop while heat is being added to it.

4. This would occur if heat loss from the place (by radiation into space) went on at a greater rate than heat was being added by the sun.

Procedures (continued)

C. Students may have to repeat this procedure in order to see the desired change. Even after the rate of addition decreases, the water level will continue to rise if water is still being added more rapidly than it drains out.

Interpretations

5. Even though heat is being added at a diminished rate after the solstice, it is still being added at a greater rate than it is being lost.

FOR FURTHER ACTIVITY

If water is added to a cup at a very low rate, water loss will exceed gain and the water level will decrease. This simulates the condition in winter in which heat loss is greater than heat gain. If the rate of addition of water is increased very slowly (simulating the increase of heat received after the solstice) the water level will continue to drop for a time. Not until the rate of addition equals the rate of loss will levels stop falling.

INVESTIGATION 11.3: An Effect of Rotation

Imagine the earth as a stationary globe with a smooth surface. Winds produced in the atmosphere of such a globe would be very predictable and unchanging. Warm air would rise near the equator and flow aloft toward the cooler poles. Air at the poles would descend and flow along the earth's surface toward the equator. Figure 11.4 is a diagram of expected wind patterns on a smooth, non-rotating earth.

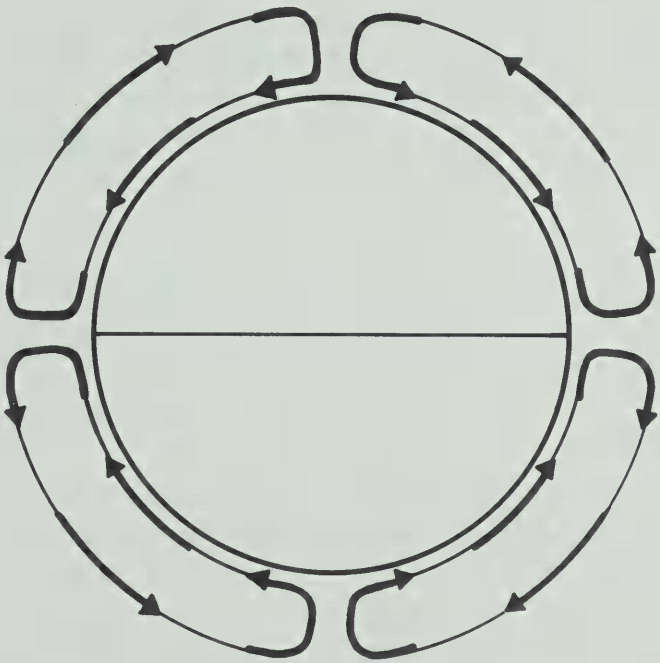


Figure 11.4. Expected Wind Patterns on Non-Rotating Earth.

Large-scale wind patterns on earth do not follow this idealized pattern. In this investigation you will consider one reason for the fact that surface winds in the northern hemisphere do not always blow from the north.

Materials (per team)

Straight edge
Paper

<u>Procedures</u>

A. Use the index finger of one hand to hold a sheet of paper down on your table top. Hold the paper firmly enough to allow it to be rotated by an assistant without allowing the center of the paper to change its location. With your other hand, hold a pencil with its point on the paper and near your index finger. Close your eyes and pull the pencil directly toward you, drawing a straight line.

B. Repeat Procedure A, but this time have another member of your team rotate the paper while you are drawing the line.

Interpretations

1. What is the effect of attempting to draw a straight line on a rotating surface?

TEACHER MATERIAL

INVESTIGATION 11.3: An Effect of Rotation

For most purposes it is possible to think of the earth as being stationary. In considering wind patterns, however, it is necessary to recognize that the earth is rotating. In this investigation students are introduced to the general problem of "straight" lines in moving frames of reference. In the following two reading selections the information will be applied to specific observations concerning climate.

Procedures

A. No comment.

B. Students may have to repeat the procedure several times before producing smooth curves.

Interpretations

1. The lines are curved. Students may notice that the direction of curvature depends upon the direction in which the paper is rotated.

CORIOLIS

As the Earth rotates everyone on it moves east.

A person who "sits still" all day actually travels quite a distance in 24 hours. At the equator the distance is about 25,000 miles. It takes 24 hours for the Earth to rotate once, therefore, a person at the equator is continually moving at a speed of about 1,000 miles per hour. See Figure 11.5.

Since everyone and everything around this person is also moving at the same rate there is no feeling of speed. Think of riding in a fast train. You may be moving at 100 miles per hour relative to the ground. But your fellow passengers are also moving at the same speed. Therefore, they are not moving at all relative to you.

In the moving train you can walk easily. You can even go into the next car of the same train. That is because this car is also traveling at the same speed relative to the Earth.

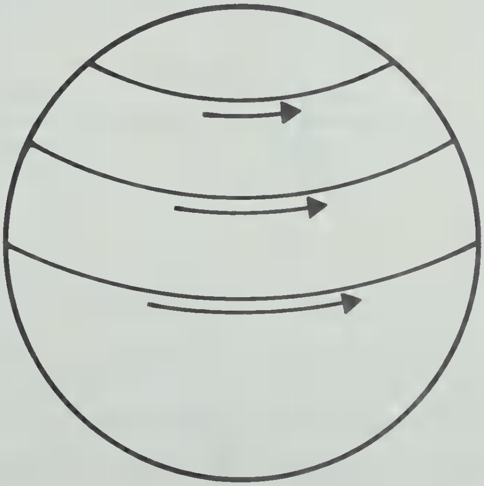


Figure 11.5. Speed of Rotation is Greatest at the Equator.

Of course you would not wish to try to get off a train moving at high speed. Neither should a person standing on the ground try to get onto the train. Changing from the train to ground or vice-versa would be extremely dangerous.

A similar effect is observed when any object moves from one part of the rotating earth to another. It is called the Coriolis Effect.

Figure 11.6 tells distances traveled in a day and speeds of places at different latitudes on earth. (What do you suppose would be the distance and speed for a person at one of the poles?)

Figure 11.6. Table

LATITUDE (degrees)	DISTANCE (miles)	SPEED (miles/hour)
0	25,000	1,000
15	23,000	966
30	21,000	866
45	17,000	707
60	12,000	500
75	6,000	258

As an example of something which changes latitude, think of the projectile from a large cannon. Suppose the cannon is at 30^{o} North Latitude. Figure 11.6 states that when the cannon ball is "stationary" in the cannon before firing it is actually moving eastward at 866 miles per hour. Now suppose the cannon is pointed directly north and fired.

As it moves through the air toward the north, the cannon ball continues to move eastward at 866 miles per

hour. As it passes over the Earth, the points below it are not moving to the east as rapidly as the projectile is. The points on the Earth fall "behind," that is, to the west. When the projectile comes to the ground it will not be north of the cannon. It will be somewhere east of north.

The amount the cannon ball veers depends upon several things. The latitude, the speed of the projectile, and the distance it travels are all involved. In a distance of 120m the veer would amount to only two or three millimeters. Over a range of 2500m the projectile would drift a distance of 200m. The large "Big Bertha" guns of World War I fired projectiles at Paris from a distance of 70 miles. The gunners had to allow for the Coriolis Effect. If they had not, the projectiles would have missed their target by nearly a mile! You saw something of this sort in the last investigation. When you tried to draw a straight line on a rotating paper, the line turned out to be curved.

In the Northern Hemisphere things moving north or south veer to the right as shown in Figure 11.7. This has a profound effect on the paths of large-scale winds.

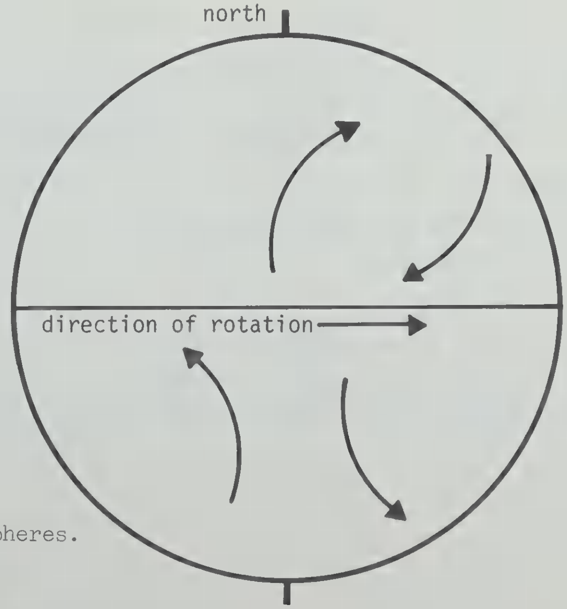


Figure 11.7.
Paths in Northern
and Southern Hemispheres.

GENERAL CIRCULATION OF THE ATMOSPHERE

Because the earth rotates, winds do not follow regular paths from poles to equator along the surface. Instead, over large areas of the earth there are winds moving from easterly and westerly directions.

Warm air at the equator rises along a belt of low pressure. This low pressure belt is called the "doldrums." It is characterized by heavy rains and little wind. The air which has risen moves poleward in the upper atmosphere. At latitudes near 30°N and 30°S the air has cooled and descends toward the surface, causing a belt of high pressure.

As the descending air nears the earth's surface, part of it is diverted toward the south and part toward the north. The Coriolis Effect causes air moving toward the equator to be deflected to the west. The result is a belt of easterly winds called the "trade winds." The descending air that moves poleward is deflected toward the east, resulting in a belt of winds known as the "westerlies." (Recall that wind direction names indicate the direction <u>from</u> which a wind blows.)

Near 60° latitude another zone of rising air exists. Aloft, this air flows toward the poles, where it descends. At the surface this cool air flows toward the equator and is deflected by the Coriolis Effect, resulting in the "polar easterlies."

Figure 11.8 shows an idealized general circulation of air and the resulting wind belts of the earth. The pattern shown is broken in many places by the presence of continents, changes in rates and areas of heating and friction. However, the idealized general circulation provides a useful starting point for understanding why prevailing winds do blow.

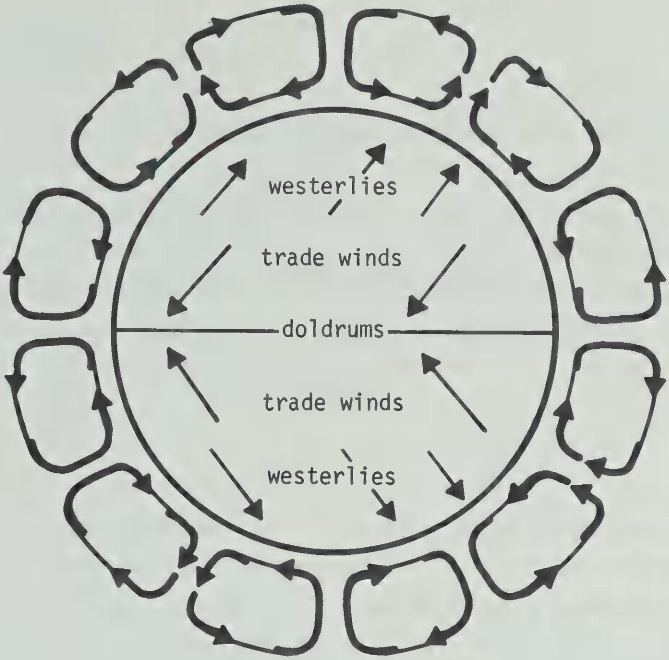


Figure 11.8. Wind Belts of the Earth.

Problems

1. In Sections One and Two of this course you developed a model for the relationship of the earth and sun. How might you use the pattern of prevailing winds on the earth as an argument <u>against</u> a model in which day and night were caused by the sun traveling around a non-rotating earth?

TEACHER
MATERIAL

GENERAL CIRCULATION OF THE ATMOSPHERE

The treatment of general circulation is quite simplified. A detailed analysis of circulation can soon become a complicated task of memorization rather than an understanding of process. For this reason, cyclones, anticyclones, pressure cell migration, etc. have been omitted.

Problems

1. Wind patterns in the Northern Hemisphere should take a north-south path on a stationary earth. A way to explain observed wind patterns is to attribute the deflection of the Coriolis Effect--the result of north-south movement on a rotating sphere.

LANDSCAPE AND CLIMATE

Sections Nine and Ten dealt with landscape and with large-scale features of the crust of the earth. When you think of the great mountain ranges of the earth perhaps you now think of the processes that produce such mountains. Just as the mountains are a result of some earth processes, they are the cause of others. Mountain ranges have a very great effect on climate.

Air which is close to sea level is under greater pressure than is air higher up. This results from the greater weight of air pressing down on it. If air rises, as it will when moving air encounters a mountain range, it expands. As you know from your investigations with clouds, expansion of air can result in the formation of clouds.

Thus areas on the windward sides of mountain ranges can be expected to receive more precipitation than do those which are on the downwind side of the same range. In South America, areas downwind from the Andes are likely to be dry and desert-like.

You have already considered the origin of prevailing winds (winds which blow from a particular direction through large parts of the year). Perhaps you can now understand how these winds, when combined with major landscape features, can be an important influence on the climate of an area.

The thinner air at higher elevations has less ability to absorb heat from the sun-warmed ground, and as a result temperatures in mountainous areas are likely to be lower than temperatures at sea level. The thinner air is less able to hold heat. Cities at higher elevations experience greater variations in temperature between day and night. While people living close to sea level are protected from intense sunlight by a thick blanket of air, people at

higher elevations are not. At high elevations a person may feel quite cold while standing in the shade but quite warm just a few feet away if he stands in direct sunlight.

Several effects of mountains on climate have been mentioned. But, as you remember, climate is the single greatest factor in determining the type of soil which will be present in a place. High areas, in which freezing and thawing is common, are weathered in different ways than are lowlands. Glaciers exist in the climates of high mountains of the United States and Canada. Their effect on the landscape is extreme. In desert areas, dry winds sandblast the landscape into forms which are not found in moist areas. Figure 11.9 shows the effects of erosion in a dry area.

The shape of the land affects climate, and the climate affects the landscape.

Figure 11.9. Wind Erosion in Desert Climate.

Problems

1. What effect does landscape have on the climate of the place in which you live?

2. Do you think that the altitude of City Q could be having an effect on its temperature pattern?

TEACHER
MATERIAL

LANDSCAPE AND CLIMATE

Students should recognize that the "rain-shadow" effect of mountains may not be restricted to the immediate vicinity of the mountains. Uplift of air, resulting in increased precipitation, may start as much as 25 miles upwind from the mountain barrier. Once triggered by uplift, precipitation may continue for some miles downwind from the crest of the range. The overall, large-scale effect is that stated in the text.

An interesting relationship between the effects of prevailing wind directions and mountain barriers is shown by the Andes. You may wish to present this as a problem to the students.

North of about 25° South Latitude a dry area lies to the west of the Andes despite the proximity of the Pacific Ocean. To the south, the dry region is to the east of the Andes. What would account for this pattern?

Students who recall the general circulation pattern may recognize that in the northern area winds are from the east, generally, and hence the western side of the range is downwind and arid. South of the latitude mentioned, the westerlies prevail, causing the eastern side of the range to be in the rain-shadow.

Problems

1. Students responses will vary.

2. The cooler average temperatures of City Q (Quito) result from its 9,300 foot elevation. It now seems likely that City Q is near the equator but at high elevation.

Students familiar with world geography may remember that there are only two places where the equator crosses high mountains, South America and Africa. It seems likely that City Q should be in one of these localities.

OCEANS AND CLIMATE

As you might expect, areas close to oceans are generally more humid than are locations farther inland. Oceans have other effects, too.

Your experience with heating samples of water and of soil has shown you that water is more resistant to temperature changes than is land. Oceans act as great reservoirs of heat. As a result, places which are closer to oceans are likely to have far smaller temperature ranges than are places which are inland.

The temperature leveling effect is strongest when prevailing winds blow from the oceans toward the land. England, on the west coast of a continent, has a climate which is moderate. This is a result of the presence of the Atlantic Ocean. Cities at similar elevations and latitudes, but on the east coasts of North America or Asia, are not as strongly affected by the oceans they are near. Their climates reflect greater variations in weather.

Places far from oceans have more variable climates than do those which are closer to coasts. Oxford, England, has an annual average temperature range of $13^{\circ}C$, while Berlin, Germany, at roughly the same latitude, has a range of $20^{\circ}C$.

Problems

1. What effect does the distance of oceans from your locality have on climate?

TEACHER MATERIAL

OCEANS AND CLIMATES

The principles outlined in the text are illustrated by the climates of most localities in North America. You may wish to give some examples after students have had an opportunity to consider the problem.

Portland, Oregon; Omaha, Nebraska; and Boston, Massachusetts; represent the west coast, middle, and east coast of the continent respectively. All are at roughly the same latitude, and altitude. Portland and Boston have 44 and 45 inches of rainfall per year, respectively, while Omaha has 29 inches. This results from the proximity of Portland and Boston to oceans.

As with temperature ranges, averages may be deceiving in expressions of rainfall. Portland's rain is heaviest during the winter months, while Boston's precipitation is more evenly distributed throughout the year.

Omaha has an average annual temperature of 11°C, while the two coastal cities are cooler, each about 7°C. As would be expected, Omaha has the greatest temperature range (31°C), the east coast city of Boston the next greatest (25°C) and the west coast city, Portland, the least (16°C).

Problems

1. If students are not certain what role their distance from an ocean is taking in affecting local climate, you may wish to re-phrase the question as, "What would be the effect of moving our location closer to (farther from) the ocean?"

Section Twelve:

Developing Other Models

PREVIEW

In Sections One through Four students were led toward an understanding of their location on earth and of the positional and dynamic relationships between earth and sun. Subsequent units focused on earth processes with underlying themes of time and change. Section Twelve sets the earth and sun against the larger backdrop of the skies. It is hoped that students will come to appreciate something of the vastness of this stage on which our home planet plays its small part.

Our approach to the role of earth and sun in the universe is partly historical and partly technological. Simple versions of some of the tools of astronomers are developed and used by students. With such tools astronomers have made observations contributing to development of the current models of the galaxy and universe.

As in earlier sections, treatment of the topics in this section is not intended to be comprehensive. Students are merely being shown that the entire universe does not revolve about the earth (in either a literal or a philosophical sense). Some students may be disappointed at the cursory

treatment of a subject they find interesting. For them the text should provide numerous springboards from which they may go off to follow their particular inclinations (construction of telescopes, observations of stars and planets, research in cosmology) while the class proceeds. It is better in any case to leave students with a desire to learn more (which they could conceivably do on their own) than to belabor a subject until interest is completely appeased.

Since conditions for viewing the sky may not be consistent students should again be referred to Appendix D containing suggested observations. If these observations have been made in advance and recorded, students will find classroom work on brightness of stars, color, etc., less abstract and more meaningful.

Section Twelve:

Developing Other Models

ANCIENT BELIEFS ABOUT THE UNIVERSE

For as long as man has been on earth he has observed the stars. A stone tablet found in the last century shows a record of the movements of the planet Venus. The tablet was made by the Babylonians about 4,000 years ago. This (Figure 12.1) is the oldest known astronomical record; but even before he kept written records, man had probably named many of the stars.

The Egyptians devised useful calendars thousands of years ago. Early Egyptian agriculture was aided by star observations. They raised their crops along the valley of the Nile River. Each year at flood stage the river overflowed into the fields, providing needed moisture to a desert-like soil. The Egyptians needed to know when to expect this flooding. They could then plan the best time to plant and to cultivate their crops. Over the years they observed that the floods always took place several days after the bright star, Sirius, rose at the same time as the sun. This occurred every 365 days. Thus, agricultural needs led to the invention of a calendar.

The Phoenicians and the Polynesians used their knowledge of the regular motions of the stars in navigation on long sea journeys. During the daylight hours, the length and direction of shadows cast by the sun were observed. These allowed ancient man to determine time. The Greeks perfected the gnomon, the instrument you worked with earlier. A gnomon allows an observer to tell time, direction and latitude. It also gives information concerning the start of seasons and the length of the year.

These are examples of direct and practical uses to which astronomical observations were put. Early man also wondered about the meaning of his observations. In his imagination he put together models in attempts to explain the relationship of earth and sky.

Until about five hundred years ago most men were convinced that all objects in the universe--the sun, moon, planets, and stars--moved around a stationary earth. The ancient Egyptians thought that the sun traveled by boat each night from the western horizon (where it set), to the eastern horizon (where it rose). (This would be like our idea of the sun setting in the west and rising in the east.) When the "goddess of the sky" bent her starry body over the earth, stars could be seen.

Another ancient model proposed that the earth was covered by a huge bowl, or dome, resting on mountains. Stars could be seen through holes in the dome. The dome model was a popular one. The early Sumerian model of the universe was a dome fixed high above a flat earth. The air, sun, moon, planets, and stars moved <u>between</u> the dome and the earth.

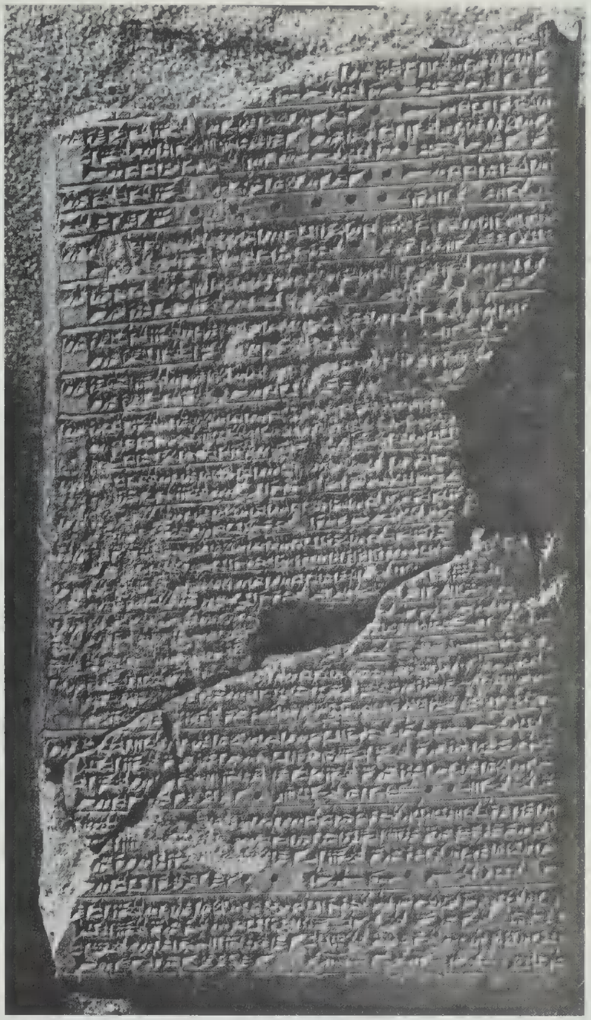


Figure 12.1.
The Venus tablet.

Thales, a Greek philosopher who lived about 600 B.C., thought that a dome floating above the flat earth contained the sun, moon, stars, and planets. He also believed that the earth rested on and was surrounded by water.

Several hundred years later some Greek astronomers rejected the flat-earth model. They began to write of a spherical earth. Still they placed it in the center of the universe and assumed that all other objects circled around it.

The idea of an earth-centered universe was accepted by most people until the 16th Century. Records of the motions of stars and planets had been in existence for many years. However people had not interpreted the records in the way we do today.

As you have discovered, the process of creating a model can be complex. First, observations must be gathered to form the basis for ideas. Often, while a model is being developed, there are opportunities to make predictions and test them. For example, consider the central position of the earth in the ancient models of the universe. If the sun travels around the earth once a day, it is possible to predict how fast the sun must be going. The only information needed to make such a calculation is the distance from earth to the sun. The greater the distance, the faster the sun must travel to complete a circle once a day.

Of course, it is impossible to measure the distance to the sun with a ruler. Therefore the prediction and testing had to await the discovery of a method for measuring distance indirectly. When the method and necessary instruments were developed, calculations showed that the sun would have to travel 25 million miles an hour to go around the earth once a day.

QUESTION FOR DISCUSSION

1. Can you think of a way in which the distance to the sun or a distant star <u>could</u> be measured?

TEACHER MATERIAL

ANCIENT BELIEFS ABOUT THE UNIVERSE

Several books could be (and have been) written on the history of astronomy alone. In the past few pages we have only touched upon the subject and suggest that you also avoid going into great detail. If one of your students is particularly interested in the study of ancient scientific history, you may wish to have him read further on the historical development of astronomy as an "out of class" project.

You might point out that astronomy has been studied seriously by people of many different civilizations for thousands of years in the past and probably will be studied for many years in the future.

Observations in astronomy have been of interest to man for both practical and philosophical reasons and many models have been suggested to "explain" the universe and its many parts. During class discussion continue to stress that models have changed, are changing and will continue to change. That is the very essence of a model.

QUESTION FOR DISCUSSION

1. Students should recall the triangulation method of measuring distance indirectly (Investigation 5.3). Variations of the triangulation method will be discussed in later material. Estimation of distances to far stars involving magnitude measurement is also presented.

MEASURING DISTANCES TO STARS

A Problem Of Too Many Miles

The mile, or in many countries the kilometer, is a convenient unit to indicate distances between cities, capitals of the world and so on. The average distance between the earth and the sun is about 93 million miles (93,000,000 miles). But stars are so far away from earth that the mile becomes a very awkward unit for describing distances. For example, the star Proxima Centauri is 25.8 trillion miles from earth. Written out this would be 25,800,000,000,000 miles. It would be very clumsy to use miles to describe distances to stars. To solve this problem scientists use the term "light year" instead of mile in describing the vast distances to stars. What is a light year? It is the distance light travels in one year. Let us see how a light year is determined. The speed of light is 186,000 miles per second. To find out how many miles there are in one light year we would have to multiply 186,000 miles per second times the number of seconds in a year. You could do this yourself, but to save you time, the calculation is described below.

There are 60 seconds in a minute, 60 minutes in an hour, 24 hours in a day and 365 days in a year. So all there is to do is to multiply all these numbers to find the number of seconds in a year:

1. 60 seconds x 60 minutes = 3,600 seconds per hour
2. 3,600 seconds per hour x 24 hours = 86,400 seconds per day
3. 86,400 seconds per day x 365 days = 31,536,000 seconds per year

---

One light year = 31,536,000 seconds per year x 186,000 miles per second = 5,865,696,000,000 miles or approximately 6 trillion miles! (6,000,000,000,000)

To find the distance of Proxima Centauri in light years, divide the distance in miles (25.8 trillion) by the number of miles in one light year: $\frac{25,800,000,000,000}{6,000,000,000,000} = \frac{25.8}{6} =$ 4.3 light years.

You will generally find that distances to stars are listed in light years rather than in miles. One method of measuring should be familiar to you.

In Section Five you learned how to measure distances indirectly. As you may recall, a baseline is established and angles of lines of sight from the baseline to the object are measured. From these measurements the distance from baseline to object may be calculated.

The longest "baseline" that may be established on Earth is about 8,000 miles (the diameter of the earth). Because 8,000 miles is such a short distance compared with the distance to even nearby stars, any baseline on Earth is relatively short. As a result, lines of sight toward a star from different locations on Earth are nearly parallel.

No matter how long you make a baseline on Earth, lines of sight to a star form the sides of a triangle that is very long and narrow. Each angle at the baseline seems to be 90°. To determine the distance to a star, astronomers use photography and a much longer baseline than can be set up on Earth.

The line of sight to a nearby star is recorded from a place on Earth. The star is sighted again from the same place six months later. During this time, however, the earth has moved around to the other side of the sun.

Since the average distance between the sun and the earth is 93 million miles, the baseline used by astronomers is twice that, or 186 million miles (Figure 12.2). With such a long baseline, they can measure the angles formed by the lines of sight to the star and the baseline. They can then calculate the distance to the star in much the same way you measured distance to objects by using triangles in Section Five.

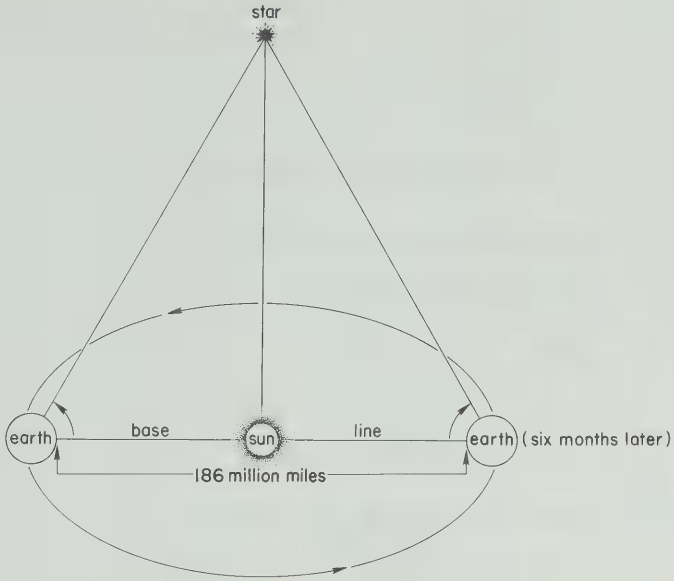


Figure 12.2. Finding distance to a star.

QUESTIONS FOR DISCUSSION

1. Why do you think the figure 6,000,000,000,000 is used to represent miles in a light year instead of the figure 5,865,696,000,000 which is more accurate?

2. If a star was calculated to be 36 trillion miles away, what would this distance be in light years?

3. If a star was calculated to be 3 trillion miles away, what would this distance be in light years?

TEACHER MATERIAL

MEASURING DISTANCES TO STARS

A Problem Of Too Many Miles

The term "light year" to describe distances to stars is found in nearly all books dealing with astronomy. For this reason we feel it important for students to understand how a light year is calculated and why it is a useful term. The actual calculations would be tedious for students and, other than as practice in simple arithmetic, probably of little educational value.

Students should realize that measuring the distance to a star is much more difficult than measuring relatively short distances. You might wish to mention that figures involving trillions, or even billions, are almost beyond the ability of people to visualize, whether they describe distances or amounts of money.

QUESTIONS FOR DISCUSSION

1. The figure 6,000,000,000,000 miles is close to the calculated figure and makes expression of the number of light years easier.

2. $36 \text{ trillion miles} \div \dfrac{6 \text{ trillion miles}}{\text{light year}} = 6 \text{ light years}$

3. $\dfrac{3 \text{ trillion}}{6 \text{ trillion}} = \dfrac{1}{2} \text{ light year}$

Note:

Some students may realize that since the distance of stars can be calculated by triangulation using the diameter

of the earth's orbit as a baseline, such calculations are based on the model that the earth revolves about the sun. You may wish to ask this in the form of a question for class discussion.

Triangulation is only useful for measuring the distance of stars relatively close to us. In the next investigation another method of measuring distance is discussed.

INVESTIGATION 12.1: Distance and Brightness

Distances to stars relatively close to us can be measured by the triangle method. But what about more distant stars? If all the stars gave off the same amount of light, then it might be possible to use their brightness to measure distance.

In this investigation, you will look for a relationship between distance and brightness.

Materials

Light meter
Lamp with bulb, 200-watt
Meter stick

Procedures

A. A light meter is an instrument used to measure the brightness of light from an object. It is made up of a solar cell, which produces an electrical current when light strikes it, and a meter that indicates the amount of electrical current produced. Practice taking light readings in various parts of the room. Notice how the needle of the meter changes position as you go from a bright area to a darker one.

B. Copy Figure 12.3 in your notebook.

DISTANCE	METER READING
1 meter	
2 meters	
3 meters	
4 meters	

Figure 12.3.

C. Place an unshaded lamp on a table or counter top. The rest of the room should be dark. Several teams can make use of one light source.

Record in the chart the highest reading on the light meter when it is 1m from the lamp. (Note: If two or more light sources are used, make sure that your light meter is positioned so light from only one source strikes it.)

Place the lamp 2m from the meter, then 3m and 4m, recording the readings from the meter.

Interpretations

1. What relationship do you see between distance and brightness?

2. Predict what the reading would be if you moved the lamp 6m from the light meter.

PROBLEM

1. Stars A and B give off the same amount of light. From Earth, Star A appears to be 100 times as bright as B. Compare the distance from Earth to Star A with the distance from Earth to Star B.

INVESTIGATION 12.1: Distance and Brightness

Materials

The number of teams will depend upon how many light meters can be obtained for this exercise. If only one meter is available one team can demonstrate and present their data to the class.

Unfrosted bulbs usually work better than do the common, frosted variety. With either type of bulb the orientation of the filament is critical. That is, even if the distance from bulb to meter is kept constant the meter reading may change if the bulb is rotated, presenting more or less of its filament to the meter.

Students should be cautioned not to "pin" the meters, that is, not to hold the meter so close to a light source that the needle of the meter moves past the upper end of the scale. Doing this can damage some meters.

Photographic meters are a possible substitute for milliameters hooked to photocells. However, it should be noted that these meters, because of the special purpose for which they were designed, may make the relationship between distance and brightness difficult to perceive. Try out any meter you intend to use before class so that you will know what to expect.

The distances suggested in Figure 12.3 should serve as a guide only. You may find that at distances of several meters from the source the meter readings are not appreciable. In such a case all distances should be reduced. Try, however, to maintain a simple ratio of distances, such as 20cm, 40cm, 60cm, 80cm.

Procedures

A. The light-sensitive part of the meter should be turned toward the source of light. The students should notice how the needle changes position as the brightness varies. Numerals may vary from meter to meter, but the purpose of the investigation is to observe how the meter reading changes as the distance to the light source changes.

B. No comment.

C. The lamp should not be shaded. It may be necessary to close the window drapes to keep stray light from affecting the meters. If the teams are grouped around the light source in a semicircle, they may carry out the procedures simultaneously. If two light sources are used, the lights should be at opposite ends of the room and the teams using one light should have their backs to the teams using the other light.

Interpretations

1. Answers will vary, depending upon the meters. However, all students should see that apparent brightness diminishes with distance. In fact, brightness decreases in direct proportion to the square of the distance. At twice the distance, the same amount of light falls on four times the area. Therefore, the amount of light per unit area (such as the area of the light meter) is one fourth as great. This relationship is called the inverse square law.

It is possible that some of the students will recognize this relationship once the data has been collected. Your decision as to whether or not to expect students to understand this quantitative aspect of the distance-brightness relationship will depend partly upon the mathematical background of your class and partly upon the accuracy of the data which has been collected with the equipment available. Whether or not the inverse square law is brought out, all students should be expected to recognize that at greater distances from a source the light intensity diminishes.

Some students will find graphing their data is an aid to recognizing relationships and predicting values. Others may find that graphing is an incomprehensible impediment to seeing what has occurred. Your decision as to whether or not to have students graph their results should be based on the background of the students and your willingness to assist in bringing their graphing skill up to a usable level.

2. Assuming a reading of one when the lamp is 1m away, the readings should be 1/4 at 2m, 1/9 at 3m, 1/16 at 4m, 1/25 at 5m, and 1/36 the amount of light at 6m. Numbers will vary from one meter to another.

PROBLEM

1. Star B is 10 times farther away than A.

MAGNITUDE OF STARS

In the Second Century B.C., a Greek astronomer named Hipparchus listed about one thousand stars in a catalog. Hipparchus incorrectly assumed that all stars are about the same distance from Earth. He assigned to each a number (from 1 to 6) to indicate its brightness. Stars listed as 1, or first magnitude, were the brightest. Hipparchus assigned the number 6 to the dimmest stars--the sixth magnitude stars.

Astronomers now use the term "magnitude" in two ways. Apparent magnitude refers to the brightness of a star as it appears to us. Suppose you could use a light meter to record the brightness of a star. If the star were twice as far away it would appear to be only one-fourth as bright. Or if it were only one-fifth as far away, it would look twenty-five times brighter.

Stars that appear very bright may actually give off more light than dim stars, or they may be much nearer to the earth. The sun seems very bright because it is so near Earth. It is really just an average star in terms of size and brightness.

Of course, if all stars were the same distance from Earth, those that appeared brightest would be giving off the most light.

For example, suppose you are looking at two 100-watt bulbs across the street. If one is brought nearer, it appears brighter, even though the amount of light it gives off has not changed.

After determining how far away a star is, astronomers can calculate how bright it would appear at a certain distance. They find it useful to compare the brightness of stars based on how bright they would be if they were all the same distance from Earth. The distance agreed upon is 32.6 light years. If all stars were that distance from Earth, the brightest ones

would be so because they were actually giving off more light. The term <u>absolute magnitude</u> refers to the actual amount of light given off by a star, not merely its appearance.

In Investigation 12.1 you recorded the apparent brightness of a bulb. You will now have an opportunity to determine its absolute brightness.

INVESTIGATION 12.2: Absolute Magnitude

Materials

- Light meter
- Lamp
- Four light bulbs of different wattages
- Two light bulbs of unknown wattages
- Meter stick

<u>Procedures</u>

A. Prepare a data sheet like the one shown in Figure 12.4.

	1m	2m	3m
200W			
100W			
75W			
50W			

Figure 12.4.

B. The room should be dark except for the lamp. Place a bulb in the unshaded lamp, and take a reading at a distance of 1m. Record the reading on your data sheet.

C. Repeat the procedure at a distance of 2m, then 3m. Record your data.

D. Repeat Procedures B and C using the other bulbs.

E. Determine the approximate wattage of the unknown bulbs (X and Y).

Interpretations

1. Describe the procedures you used to determine the wattage of bulbs X and Y.

2. What are the wattages of bulbs X and Y?

3. If you knew the apparent magnitude and distance of a star should it be possible to calculate its absolute magnitude?

4. If you knew the absolute magnitude of a star what observation would be needed before you could calculate its distance?

TEACHER MATERIAL

INVESTIGATION 12.2: Absolute Magnitude

Materials

Four bulbs: 50-, 75-, 100-, and 200-watt bulbs of similar size are preferable. If different wattage bulbs in this range (50-200) are more easily obtained, substitutions may be made. Bulbs dimmer than 50 watts are not recommended.

Bulbs X and Y should be the same size. Bulb X should have the same wattage as one of the bulbs used in Procedures B-D. Bulb Y should have a wattage other than those already used.

Procedures

A.-B. No comment.

C. Repeating the procedure at other distances affords another opportunity for students to observe the relationships involved in the inverse square law.

D. In general, the more wattage a bulb has, the brighter it is. Comparison of meter readings with different bulbs at various distances should help the student appreciate the difference between absolute magnitude and apparent magnitude.

E. Use a black, felt-tip pen to mark the bulbs X and Y, and blot out their wattage value.

Interpretations

1. By seeing where a reading at a known distance fits in the chart, the students should be able to estimate the wattage.

The parallel between this activity and the preceding discussion of absolute magnitude should be seen by the students. When all the bulbs are placed the same distance from the meter, their true brightness (absolute magnitude) can be seen.

2. Answers will depend on the values of X and Y.

3. Yes, if the apparent magnitude and distance of a star are known it is possible to calculate its absolute magnitude. If students have difficulty in seeing this, point out that the question is similar to, "What is the wattage of a light bulb which gives a meter reading of X at a distance of 2m?"

4. The apparent magnitude would have to be measured.

MAGNITUDE SINCE HIPPARCHUS

Many stars too dim to be seen by Hipparchus have since been viewed with the aid of telescopes. Recall that in the system devised by Hipparchus, the brightest stars had a magnitude of one and the dimmest had a magnitude of six. Today the scale has been extended to include the dimmest stars seen through giant telescopes. The dimmest stars which can be observed have a magnitude of 23.

At the other end of the scale, stars and planets brighter than first magnitude are known. The magnitudes assigned to them range from zero into negative numbers. The apparent magnitude of the sun, for example, is -28.

Figure 12.5 shows the relationship between magnitude number and brightness. The same scale is used to indicate apparent magnitude and absolute magnitude of stars.

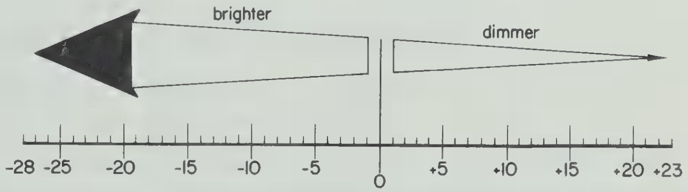


Figure 12.5. Scale showing the relationship between magnitude and brightness.

Figure 12.6 lists both the apparent magnitude and the absolute magnitude of a few objects in the sky. Decimal fractions are used to indicate place between two magnitudes. For example, a star of magnitude 2.3 is dimmer than a second-magnitude star but brighter than one that is third magnitude.

Figure 12.6.

Object	Apparent Magnitude	Absolute Magnitude	Distance In Light Years
Sirius (star)	-1.6	1.4	9
Canopus (star)	-0.7	-4.6	98
Vega (star)	0.04	0.5	27
Rigel (star)	0.14	-6.8	900
Betelgeuse (star)	0.41	-5.5	
Venus (planet)	-4.2 (at its brightest)	*	Much less than one
Full Moon	-12.7	*	Much less than one

* Do not produce their own light.

One other method of referring to the brightness of stars is often used. Greek letters were assigned to stars in the order of their brightness within a star group, or constellation. That is, the brightest star in a constellation has the first letter of the Greek alphabet--alpha (α)--assigned to it. The second brightest star in the group is assigned the second letter--beta (β)--and so on. This system is often used in star charts.

Rigel and Betelgeuse are two stars found in the constellation Orion. Betelgeuse is the brightest star in that constellation and is therefore referred to as <u>alpha</u> Orion; Rigel is second brightest and is called <u>beta</u> Orion.

The first five letters in the Greek alphabet are listed in Figure 12.7 together with the Greek symbols.

Figure 12.7.

α	alpha
β	beta
γ	gamma
δ	delta
ε	epsilon

You now know that a star which appears dim may appear so for one of two reasons. The star may not produce a great deal of light. Or it may be at a very great distance. Perhaps a combination of these two factors causes the star to appear dim.

But why should some stars produce more light (greater absolute magnitude) in the first place? You will find possible answers to this question in Investigation 12.4 and the reading material which follows it.

PROBLEMS

1. Which of the objects listed in Figure 12.6 gives off the most light?

2. Which star in Figure 12.6 would appear brightest in the night sky?

3. Which is more distant, Betelgeuse or Vega?

MAGNITUDE SINCE HIPPARCHUS

PROBLEMS

1. To determine which star is actually the brightest, students must refer to absolute magnitude. Rigel is the brightest of those listed, with an absolute magnitude of -6.8. Rigel, however, is sixth in order of apparent magnitude. When students realize that this star is about 900 LY from Earth, they may get some idea of the tremendous amount of light it gives off. Actually, Rigel has the brightness of about 18,000 suns!

2. Of the stars listed, Sirius appears brightest in the night sky, with an apparent magnitude of -1.6.

3. Betelgeuse is at a distance of 520 light years. Since the apparent magnitude of Betelgeuse is less than Vega's, whereas its absolute magnitude is much greater than Vega's, Betelgeuse must be the more distant.

INVESTIGATION 12.3: Estimating the Number of Stars in the Evening Sky (Optional)

Think back to a statement which was made earlier in this section: "Many stars too dim to be seen by Hipparchus . . ." How many stars could be seen by Hipparchus? How many stars can you see without a telescope? One hundred? One thousand? Millions? An answer to this question can be found rather easily and may prove interesting. This investigation suggests a method for finding the answer.

Materials (per student)

- Sheet of cardboard 25cm x 25cm
- Flat stick, 60cm
- Meter stick
- Scissors
- Paper clips
- Masking tape

Procedures

A. Obtain a piece of cardboard approximately 25cm x 25cm. Cut out a square opening 15cm x 15cm in the center of the cardboard. This will be the "window" through which you will make sample counts of the stars.

B. Measure 50cm from one end of the flat stick, and draw a line across it. Bend open a large paper clip so that the two loops form a 90° angle. Tape one loop to the center of one edge of the cardboard (see Figure 12.8). Tape the other loop to the stick so that the cardboard is held upright at the 50-cm mark.

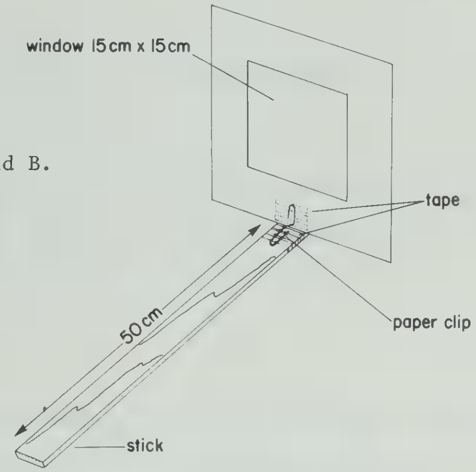


Figure 12.8.

Set-up for Procedures A and B.

C. You are now ready to use your sky window. Try to find an observation point away from street lights. When your eyes have adjusted to the darkness, hold one end of the meter stick near one eye and look through the window. Count all the stars you see in the square.

Select two other areas in the sky, and make counts. Record your three star counts.

D. Find the average of the three star counts you made. Multiply this number by 70.* This gives you an estimate of the number of stars seen in the evening sky.

Interpretations

1. Compare your estimate with those calculated by other students. How do you account for any differences?

*The total viewing area of the sky is approximately 70 times larger than the viewing area in the cardboard window.

TEACHER
MATERIAL

INVESTIGATION 12.3: Estimating the Number of Stars in the Evening Sky (Optional)

The number of stars normally visible at any one time from any one place may vary greatly, but it probably does not exceed one or two thousand as an absolute maximum.

Materials

The cardboard should be stiff enough to keep its shape. Any flat, smooth stick about 60cm long will do. Scrap wood can often be obtained from a lumberyard or school shop.

Procedures

A. An opening 15cm x 15cm is suggested. However, some students may want to work with either larger or smaller openings. If the dimensions of the opening are changed, it will be necessary to calculate a new value for the multiplier in Procedure D.

B. No comment.

C. Discuss some of the problems students might have in counting stars. For example, street lights might make viewing difficult, sky might be cloudy or hazy, obstructions might be present, etc. Students are asked to make counts in more than one part of the sky. This will reduce errors that could arise if an atypical area is selected for the first count.

D. In the example given, the average of the star counts through the 15cm x 15cm window would be multiplied by 70. The product is the estimated total count.

The formula to find the surface area of a sphere is $4\pi r^2$, (r = the radius of the sphere). Since only half of this sphere is above the horizon, the answer is divided by two. Dividing this by a^2 (a = one side of the square opening), gives N. N is the factor used to multiply the star count to get the estimate of total stars in the sky. Discussion of how the formula is derived is not important.

Interpretations

1. It is not likely that any two estimates will agree. However, they should fall within a fairly narrow range. Encourage students to discuss reasons for differences. Some of the reasons given might be variability of sky conditions or differences in eyesight. Under optimum conditions, several thousand stars can be seen at night with the unaided eye.

INVESTIGATION 12.4: Heating an Object

If you look at the stars carefully, you will notice that not all are the same color. Yellow, red, white, and blue are some of the colors you can see. In this investigation you will have an opportunity to observe an object as it is heated. This may provide a clue to star colors.

Materials (per team of four)

- Pliers
- Paper clip (straightened)
- Gas burner

Procedures

A. Hold a straightened paper clip with a pair of pliers. Put the tip of the paper clip in the hottest part of a gas flame (Figure 12.9). Observe and record the color of the tip of the paper clip as it is heated.

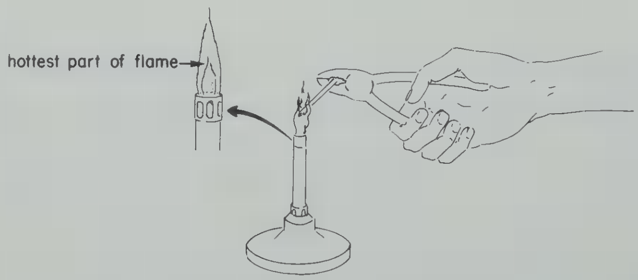


Figure 12.9.

Interpretations

1. What color changes did you observe in the paper clip as it was heated? If your flame had been hotter, you might have seen the color continue to change until it was white, and finally, blue-white.

2. If the relationship between color and temperature in stars is the same as the one you observed in a paper clip, would a red star be hotter or cooler than a yellow star?

TEACHER
MATERIAL

INVESTIGATION 12.4: Heating an Object

The color of light produced by an object is related to its temperature.

The intensity of light produced by an object increases as its temperature increases.

The color and amount of light produced by a star may be related to the temperature of the star.

Materials

A Bunsen burner or propane torch may be used.

Procedures

A. No comment.

Interpretations

1. The paper clip should be seen to change from red to orange to yellow in the flame. This is about as much color change as can be seen with these materials. With greater heat the paper clip would change from yellow to white.

2. A red star would not be as hot as a yellow star.

TEMPERATURES OF STARS

Stars differ in color as well as in brightness. One way astronomers have classified stars is according to temperature. The classes are identified by the letters O-B-A-F-G-K-M, in order from highest to lowest temperature. An easy way to remember the classes of stars in this order is to learn the sentence, "Oh Be A Fine Girl, Kiss Me!"

The Kelvin (abbreviated K) scale is used to express temperatures of stars. The temperature of a star, expressed on the Kelvin scale, is a smaller number than would be needed for the temperature of the same star expressed in degrees Fahrenheit. Examples of star colors and temperatures are given in Figure 12.10.

Star	Constellation	Color	Surface Temperature	Class
Betelgeuse	Orion	red	3,100°K (5,580°F)	M
Canopus	Carina	white	8,200°K (14,760°F)	F
Spica	Virgo	blue-white	24,000°K (43,200°F)	B
Vega	Lyra	blue-white	11,300°K (20,340°F)	A

Figure 12.10.

The temperatures given in the table are surface temperatures. The hottest stars may have interior temperatures of more than 50,000,000° K.

PROBLEMS

1. The sun is a G-type star. Within what temperature range is the surface of the sun? Use Figure 12.10. and the temperature classification system of stars to decide on your answer.

TEACHER
MATERIAL

TEMPERATURES OF STARS

Stars vary in color as a result of their temperature.

Higher temperatures correspond to bluer colors and greater light output per unit area.

PROBLEMS

1. The surface temperature of the sun should be between $3,100^{\circ}K$ (Betelgeuse-type M) and $8,200^{\circ}K$ (Canopus-type F). The accepted temperature is about $6,000^{\circ}K$.

SIZES OF STARS

The brightness of a star depends upon its temperature and its size. If two stars have the same temperature, the one with the larger diameter will give off the most light. If astronomers know the color of a star and its absolute magnitude, they can calculate its size. A given surface area on a white star sends out more light than the same area on a red star.

From the color of a star astronomers can tell how much light is given off per unit of area. From this, it is possible to calculate how large the star must be.

The largest stars are the red giants. Some have diameters 400 to 500 times the diameter of the sun. Betelgeuse, in the constellation Orion, and Antares, in the constellation Scorpius, are red giants. The diameter of Antares is 450 times that of our sun. Figure 12.11 shows how the size of Antares compares with the size of our solar system.

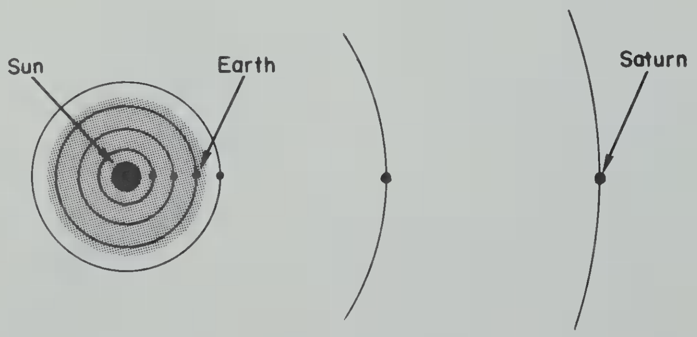


Figure 12.11. If the star Antares were at the center of our solar system, it would occupy the shaded area.

The smallest stars are the white dwarfs. Some are no larger than planets in our solar system.

The range of star sizes in the universe is enormous. The giants are about 150,000 times larger than the smallest. Our sun is somewhat smaller than average among stars.

DENSITY OF STARS

Density is found by dividing the weight of any object by its volume. A ping pong ball is less dense than a golf ball. If you have ever made a snowball, you know that the tighter you pack the snow, the more compact, or dense, the snowball will be. Freshly-fallen snow is not very dense; it is made up of flakes that are loosely packed.

Astronomers have learned that the least dense stars are the red giants. The volume of such a star may be millions of times greater than that of the sun, but it may contain only 50 times more matter. The density of the red star Antares is less than two ten-millionths that of the sun. The air around you is about 10,000 times more dense than the material making up Antares!

The most dense stars are the white dwarfs; some are nearly 200,000 times more dense than the sun. Difficult as it is to imagine, a cubic centimeter of material from such a star would weigh nearly 2½ tons on Earth (Figure 12.12).

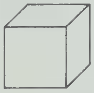


Figure 12.12. If a block of material this size was taken from a white-dwarf star, it would weigh nearly 2 1/2 tons on Earth.

Now you see how difficult it is to speak of an "average" star, even though that term was used earlier in referring to the sun.

The temperature of many stars is several times greater than the sun's but others have temperatures that are much lower. Variation in the amount of light given off by different stars is great--from several hundred thousand times brighter than the sun down to about one-millionth as bright.

NOVAE

Occasionally stars have been seen to change suddenly in brightness. They may increase to 100,000 times their normal brightness. Such a star is called a nova, meaning "new star." Understandably, these were thought to be new stars by ancient astronomers who recorded them as early as 134 B.C. Tycho Brahe, a Danish astronomer, described a nova in 1572 as follows:

> "One evening, when I was contemplating as usual, the celestial vault, . . . I saw with inexpressible astonishment, near the zenith, in Cassiopeia, a radiant star of extraordinary magnitude.
>
> "Struck with surprise, I could hardly believe my eyes . . . The new star . . . resembled in every way other stars of the first magnitude. Its brightness exceeded that of Sirius, and of Jupiter. It could only be compared with that of Venus. Persons gifted with good sight could distinguish this star in daylight, even at noon day, when the sky was clear."

Tycho's star as it came to be called, remained visible for about a year and a half.

Tycho's star is now believed to have been an exploding star. While some novae experience more than one explosion, the majority do not. It is believed that such explosions take place near the surface, with the star literally blowing off its top. Once in a great while, as with Tycho's star, an explosion occurs that really is most unusual. This is called a supernova, and the brightness of such a star may be equal to about 200 million suns. Johannes Kepler, a German scientist, observed another supernova shortly after Tycho's. This one appeared as bright as Jupiter and lasted about as long as Tycho's star.

The earliest recorded star explosion visible to the unaided eye occurred in the year 1054. In that year, the Chinese noted that a "guest star" appeared in the constellation Taurus. As bright as Venus, the nova was visible in daylight for 23 days and in the night sky for about two years. Through telescopes it is still possible to see the remains of this 1054 explosion, now called the Crab Nebula. If you are fortunate you may see a supernova in your lifetime.

SOME TOOLS OF ASTRONOMY

Most observations of the sky which have been suggested so far were made by the people of hundreds of years ago. These people were able to see patterns of stars in the sky. They could notice differences in brightness between stars. They were able to see that stars were various colors.

Changes in positions of stars from night to night and from season to season were noted by people of many different cultures. An observatory to study the motions of heavenly objects was built in Korea in 647 A.D. It is still standing today. During the first 1,000 years of its operation the Koreans recorded 66 eclipses of the sun and the positions of nearly 1,500 stars.

In the 18th Century excellent observatories for recording the movements of the stars were built in India. Large instruments were used to measure angles. The observations made were more accurate than any before.

A fine observatory was established by Tycho Brahe of Denmark in the late 16th Century. His instruments were very large and accurate. Tycho himself was a very careful observer and made very precise observations.

The tools and methods you used earlier in the course were used by early astronomers. The instruments were fairly simple to construct. Gnomons and astrolabes have been in use for centuries. Attempts at finding the distance to the sun were made in the Third Century B.C.

None of the early observers had the use of telescopes, though, for these were not invented until early in the 17th Century. The first astronomer to use a telescope was Galileo Galilei of Italy. Figure 12.14 shows one of the telescopes made by Galileo in 1610.

After looking through his telescope at the night sky, Galileo wrote: "Beyond the stars of the sixth magnitude

Figure 12.13. Tycho in his observatory.

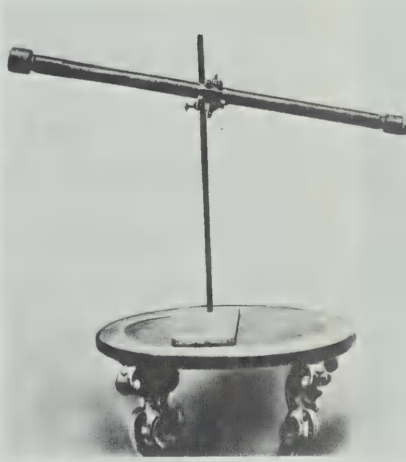


Figure 12.14.

you will behold through the telescope a host of other stars, so numerous as to be almost beyond belief."

Galileo's telescopes were small; the lenses were less than five centimeters in diameter. Yet, small as the telescopes were, he made several important discoveries. Galileo saw that there were mountains on the moon and spots on the sun. He was the first to discover that another planet (besides our own) has a satellite. In fact, he saw four moons revolving around Jupiter. And he discovered that Venus goes through phases, just as our moon does.

These observations helped convince Galileo that the sun--not the earth--was the center of our solar system.

Telescopes have been made both larger and better since Galileo's time. Other instruments have been designed to aid in observing the sky. In the next investigations you will construct some modern astronomical instruments and consider the ways in which they may be used.

FOR FURTHER ACTIVITY

1. Why did Galileo's observation of the moons of Jupiter help convince him that the earth was not the center of the solar system?

2. What does the fact that Venus shows phases tell you about its location in the solar system?

3. What is located at Stonehenge?

TEACHER
MATERIAL

SOME TOOLS OF ASTRONOMY

A great deal of astronomy can be, and has been, carried on without telescopes and other sophisticated instruments. Students should see that astronomy has not been the province of one nationality or culture.

FOR FURTHER ACTIVITY

It is difficult to predict the limits of student library research into the suggested topics. Among other things, they may find that:

1. Galileo observed moons which he concluded were revolving about Jupiter. Before his time, prevalent thought was that all heavenly bodies revolved about the earth. Since he had found one exception, might there not be others? This line of thought led him to the conclusion that all bodies in the solar system revolved about the sun and not the earth.

2. The fact that Venus (and Mercury) shows phases while other planets do not indicates that these two planets are closer to the sun than is the earth. Students could demonstrate this by using a light source to represent the sun and a sphere to represent a planet. Only when the "planet" is relatively close to the "sun" (from the observer's point of view) will it show "phases," that is, be partially lighted and partially dark.

3. Stonehenge was built about 3500 B.C. The positioning of its massive stones suggests that it was used to mark sunrise locations at solstices and equinoxes.

INVESTIGATION 12.5: Observing Pathways of Light

The telescope and many other tools of the astronomer are devices which use light in different ways. Before working with these devices you should review what you know about light. A few simple observations of the way in which light behaves will possibly improve your understanding of telescopes and other tools.

Materials (per team)

Ruler or straight edge
Small flat-sided bottle, with cap
Pitcher of water
Coin
Flat-bottomed cup (opaque)
Lenses, 2

Procedures

A. Look at a coin or other small object on your work table. You are able to see the object because light reflects from it to your eye. In your notebook describe the path light takes from the source to the object to your eye.

Interpretations

1. What simple test can you suggest which would prove that light makes it possible for you to see the object?

2. Does all the light leaving the coin come to your eyes?

3. Explain your answer to Interpretation 2.

4. Do you think that light from the coin follows a straight path or a bent path in traveling to your eye?

<u>Procedures</u> (continued)

B. Sight at the coin along the edge of a ruler (as in Figure 12.15). Have a teammate view your eye, the ruler, and the object from the side.

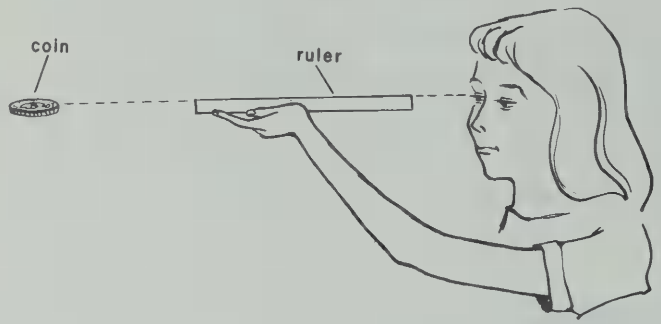


Figure 12.15.

Interpretations

5. Does the ruler point directly at the coin?

6. What does this tell you about the path followed by light in traveling from the coin to your eye?

<u>Procedures</u> (continued)

C. Draw a straight line on a piece of paper. Fill the small bottle with water, and cap it. Lay the bottle across the line. Look at the line from several different angles and positions.

Interpretations

7. Describe the appearance of the line. Does light from the line follow a straight path through the bottle and the air?

<u>Procedures</u> (continued)

D. Place a small coin in the cup. Put the cup on the desk. Then slowly move back just far enough so that you can no longer see the coin. Remain at this position, watching the top of the cup, while another member of your team very slowly pours water into it. Sight at the coin in the cup along the edge of your ruler. Have a teammate observe from the side.

Interpretations

8. Describe and explain what you observed in Procedure D.

9. What does this tell you about the pathway of light?

<u>Procedures</u> (continued)

E. Darken the room except for one nearly closed shade. Stand near the window with a lens and a sheet of paper. Hold the lens between the window and the paper.

Move the lens back and forth until the image of an object outside, such as a tree, is focused on the paper (Figure 12.16).

Interpretations

10. Describe the appearance of the image on the paper.

Figure 12.16.

Figure 12.17.

Procedures (continued)

F. Examine the two lenses and determine which one makes the print on this page appear largest.

Hold the lens of greater magnification near your eye. Hold the other a little farther away, behind the closer lens (Figure 12.17). Move the weaker lens away from you slowly until you see the image of some object in front of you in focus. This is the way a telescope works.

Interpretations

11. Describe the image obtained in Procedure F.

12. In what way can lenses and water be similar in their effects on light?

TEACHER
MATERIAL

INVESTIGATION 12.5: Observing Pathways of Light

Objects are seen as a result of light traveling from the object to the eye along straight pathways.

In some cases, light from windows or bulbs is reflected from the object to the eye. In others, the object (light bulb, heated paper clip, star, etc.) produces its own light.

Glass, water and possibly other transparent substances may bend (refract) light paths between object and eye.

Materials

The two lenses should be convex and have different focal lengths--about one inch and twelve inches. They should be about 1 1/2 inches in diameter. The lenses are also to be used in the following investigation.

Procedures

A. No comment.

Interpretations

1. Students may suggest turning off lights, thus preventing light from reaching the object, or other tests. In such cases the object would no longer be visible.

2. No, not all the light leaving the object comes to one observer's eye.

3. Several observers may view the object at the same time.

4. Student answers will vary. A test is suggested to the student in Procedure B.

Procedures (continued)

B. No comment.

Interpretations

5. Yes, the ruler points directly (straight) at the coin.

6. The light travels in a straight pathway from coin to eye.

Procedures (continued)

C. No comment.

Interpretations

7. When viewed from several angles, the part of the line beneath the bottle appears to be displaced to one side. This can be explained by assuming that light from the line is bent (refracted) as it passes from water to air (and then to your eye). Light from other parts of the line follows a straight path to the viewer's eye. Some students may point out that the light from the line also passes through glass (twice).

Procedures (continued)

D. The team should observe that the ruler is pointing at the edge of the cup where the coin appears, not at the bottom of the cup where the coin actually is.

Interpretations

8. Since light travels in straight lines through air, the side of the cup blocked the light rays from the coin to your eye. When water was added to the cup, the light rays from the coin were bent enough to reach your eye.

9. The pathway of light from coin to eye is not straight.

<u>Procedures</u> (continued)

E. The room need not be very dark. If the day is not too bright, merely turning out the lights will do.

Interpretations

10. The image is inverted and small. The convex lens--like the lens in an eye--inverts the image.

<u>Procedures</u> (continued)

F. No comment.

Interpretations

11. The image is inverted and magnified.

12. Both water and lenses have been observed to change the direction of light.

INVESTIGATION 12.6: Constructing a Telescope

Materials (per team)

- Lenses, 2
- Construction paper, 2 sheets
- Masking tape
- Scissors
- Ruler

Procedures

A. The lens with the greater magnification will be the eyepiece of your telescope. Hold this lens near your eye.

The second lens will be the objective lens. Hold the second lens at arm's length. Bring it nearer to your eye while looking at a distant object through both lenses. When the object is in sharp focus, hold the lenses steady. Immediately have one of your team members measure and record the distance between the two lenses.

B. Roll and tape two sheets of construction paper to make two cardboard tubes with slightly different diameters. One tube should slide inside the other. When extended, the combined length of the tubes should be greater than the distance between the lenses found in Procedure A. The tubes should be made just large enough in diameter to hold the lenses.

C. Use masking tape to attach the lenses to the free end of each tube as shown in Figure 12.18.

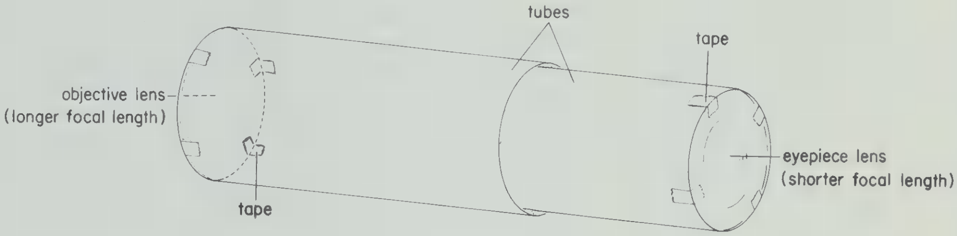


Figure 12.18. Refracting telescope assembled.

D. Look at a distant object through your telescope, and slide the tubes in or out until the object comes into focus.

Interpretations

1. Is the image you see upright or inverted?

2. Use your telescope to view several of the objects that Galileo observed in the sky.

CAUTION: Never look directly at the sun at any time.

INVESTIGATION 12.6: Constructing a Telescope

Materials

Use the lenses suggested for Investigation 12.5.

Procedures

A. If students need help determining which lens has the greater magnification, refer them to Procedure F of Investigation 12.5.

B.-D. No comment.

Interpretations

1. If both lenses are convex, the image is inverted.

2. The student can use his telescope to view the surface features of the moon. He can also view any planets visible at the time. A world almanac provides information on when and where planets can be observed.

Emphasize the caution about never looking at the sun.

FOR FURTHER INVESTIGATION (Optional)

Ask the students to predict what would happen if a concave lens instead of a convex lens was used as the eyepiece in Procedure D. If a concave lens is available, have some

students try this. (The image will be upright, as was the case with Galileo's telescope but not as large as that obtained with two convex lenses.)

PERFECTING THE TELESCOPE

Telescopes like Galileo's have lenses that bend, or refract, light moving from one transparent material, such as air, into another, such as glass (or water). These instruments are known as refracting telescopes. Many of the telescopes used by astronomers today are quite similar to his. Improvements on the Galilean type telescope were made with advances in the manufacture of large objective lenses.

However, Sir Isaac Newton in 1668, devised a telescope that did not require large lenses. Newton used a curved mirror in place of an objective lens. The curved mirror reflected light to a small flat mirror which again reflected the light to a magnifying eyepiece (Figure 12.19).

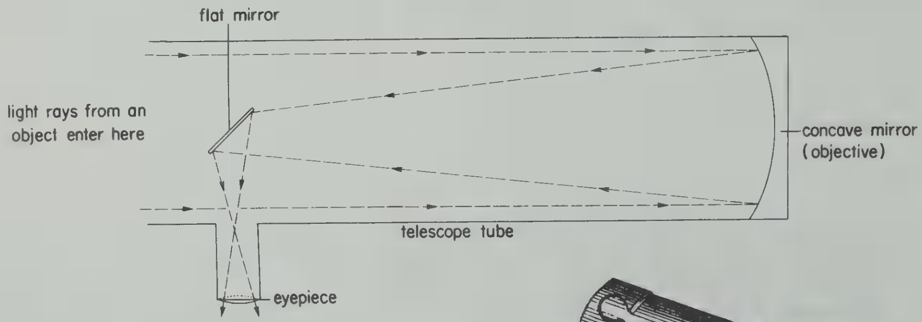


Figure 12.19.
Principle of Newton's reflecting telescope.

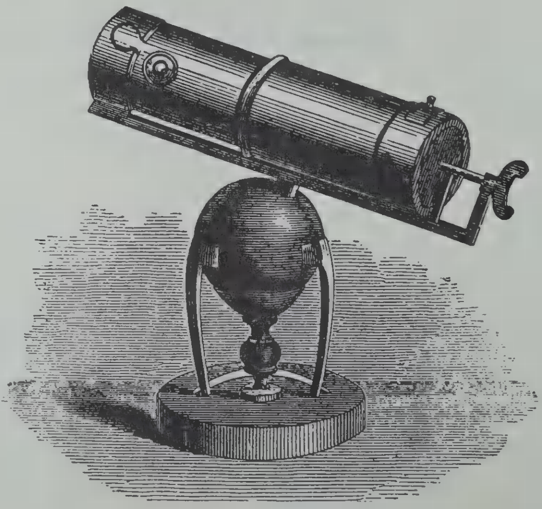


Figure 12.20.
Newton's reflecting telescope.

Galileo's telescope was a refractor; Newton's was a reflector. Each type has its purpose.

Figure 12.21. The 40-inch refracting telescope at Yerkes Observatory, Williams Bay, Wisconsin.

Refractors are often used to view large areas of the sky. When viewing planets, the observer can see surface details better with a refractor than with a reflector of the same size. Two refractors built in the 19th Century are still the largest in the world--the 36-inch refractor at the

Lick Observatory in California, and the 40-inch in the Yerkes Observatory in Wisconsin (Figure 12.21).

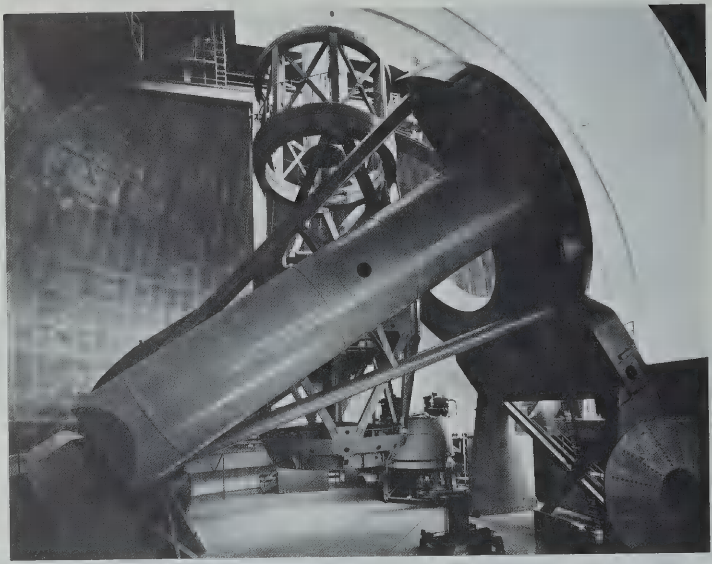


Figure 12.22. The 200-inch Hale reflecting telescope.

The reflectors are better used to show faint, distant objects in sharp detail. A 120-inch reflector is also located at the Lick Observatory. The largest telescope is the 200-inch Hale reflector at the Palomar Observatory in California (Figure 12.22).

When the large telescopes are used, a camera is placed at the eyepiece and is used to obtain a photographic record. A photograph gives the astronomer an opportunity to study the area in detail and provides for a permanent record of what is seen.

Another telescope at the Palomar Observatory is basically a combination of the reflector and the refractor. This is the 48-inch Schmidt telescope (Figure 12.23). The Schmidt is

used to photograph large portions of the sky at one time. Its field of vision is about 400 times larger than that of the largest refractor.

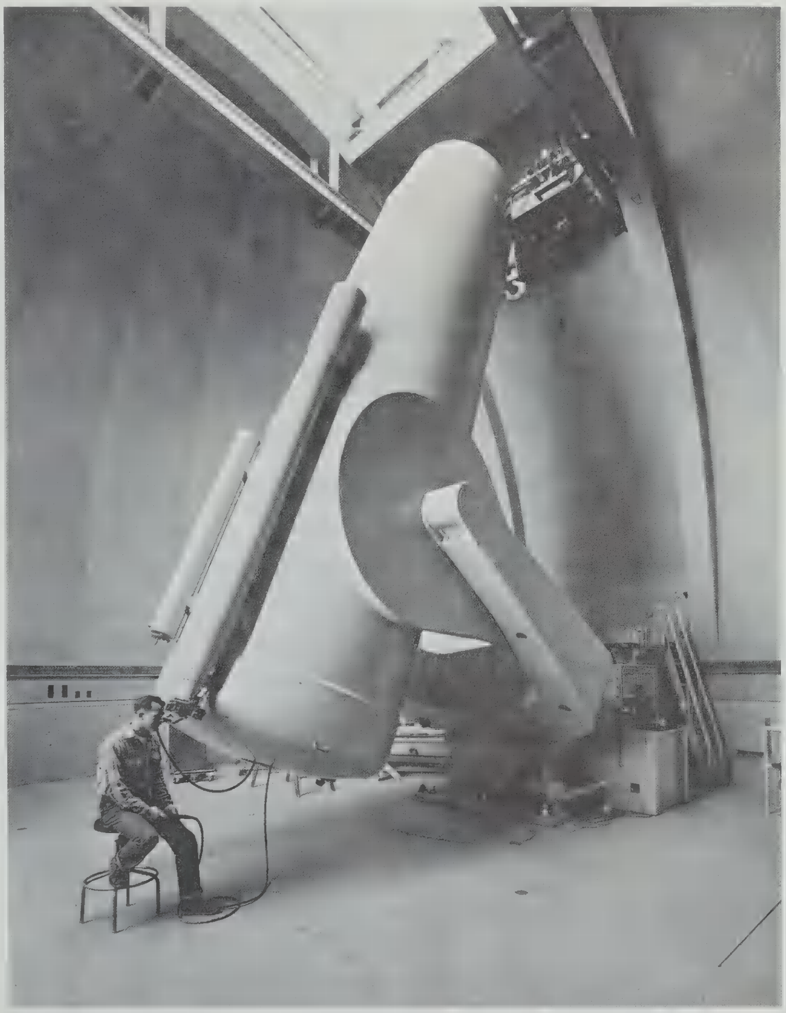


Figure 12.23. The Schmidt telescope.

INVESTIGATION 12.7: Building a Reflecting Telescope (Optional)

Materials

Concave shaving or make-up mirror
Convex lens
Small flat mirror
Light source
Modeling clay

Procedures

A. Place the mirror in an upright position with its curved surface facing the light source. The mirror and light source should be separated by ten feet or more.

B. Locate the image produced by the mirror by holding a sheet of blank paper in front of the mirror. Move the paper back and forth between the mirror and the light until the image of the light shows clearly on the paper. If necessary, dim the room lights in order to see the image clearly. Note the distance from the mirror to the point where the image is formed.

Interpretations

1. Describe the appearance of the image on the sheet of paper.

Procedures (continued)

C. Support the small, flat mirror with clay. Place it between the curved mirror and the point where the image is formed, and about 10cm from the image.

The flat mirror should be placed at an angle as in Figure 12.24.

D. Use the sheet of paper to locate the image reflected from the flat mirror. Remove the paper and examine the image with a convex lens. See Figure 12.24.

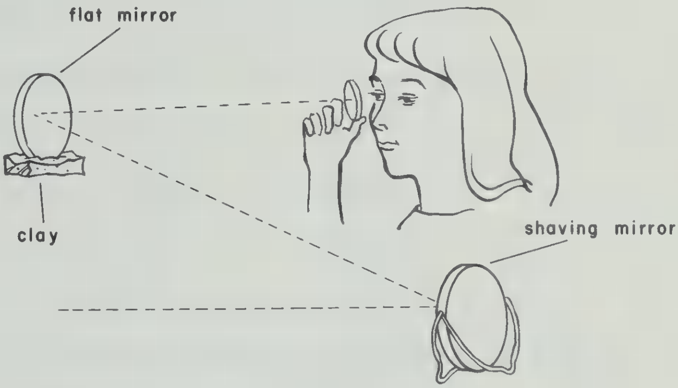


Figure 12.24.

Interpretations

2. Describe the appearance of the image.

PROBLEMS

1. The diagonal mirror of a reflecting telescope is often located directly in front of the mirror. Do you think this blocks the astronomer's view of some of the stars?

2. Some telescopes have lenses or mirrors mounted in tubes. Others, such as the one you have just constructed and the Hale Telescope (Figure 12.22) have no tubes. What do you think is the purpose of the tube?

TEACHER MATERIAL

INVESTIGATION 12.7: Building a Reflecting Telescope (Optional)

Materials

The curved mirrors which are described can be purchased at most drug or variety stores for less than one dollar.

Any small mirrors may be used for the flat diagonal mirror.

The convex lenses used earlier are satisfactory for eyepieces.

Procedures

A. No comment.

B. It will be easier to locate the image without blocking light from reaching the mirror if the mirror is canted slightly to one side. The image should be formed about 1m in front of the curved mirror.

Interpretations

1. The image will be small and inverted.

Procedures (continued)

C. No comment.

D. Be sure to test the light source by viewing it through a telescope before students use it. A source which is too bright may be harmful to view through the telescope, while one which is too dim produces an image which is hard to locate. A

25-watt bulb used in a room which is fairly well lighted provides a good compromise.

Interpretations

2. The image is inverted, not reversed left to right, and enlarged.

PROBLEMS

1. If students become involved with this problem you should have them attempt to solve it in the laboratory before turning to written resources to verify their conclusions. In the telescope described in this investigation the eyepiece and diagonal mirror may be set out of the path of incoming light by canting the mirror slightly. The resulting distortion is not appreciable. In astronomical telescopes distortion is minimized by having light reflected directly back from the objective mirror and then diverted to the eyepiece by a diagonal (see Figure 12.19).

Students who investigate the effect of the diagonal will find that it does not block part of the field of view. Instead it causes a slight dimming of the image. A second effect, which will probably not be observable with the simple, laboratory telescope, is the production of "points" around the stars being viewed. This effect is apparent in Figure 12.29, for example, where several of the brighter stars show four large points and a host of smaller ones. The points result from diffraction of light around the "spider," the four supports which hold the diagonal mirror in position within the telescope.

2. The tube provides a rigid support for the lenses and mirrors of the telescope. In larger instruments a web of beams is usually sufficiently strong for this purpose. The tube also prevents stray light from entering the instrument and distracting the observer. Since the largest tele-

scopes are generally operated in darkened observatory domes, the tube is again not essential.

INVESTIGATION 12.8: Building a Spectroscope

In addition to the telescope, astronomers use other instruments to obtain information about the stars. One such tool is the spectroscope.

Materials (per team)

- Transmission diffraction grating (3cm x 3cm)
- Construction paper (dark color)
- Scissors
- Metric ruler
- Masking tape
- Paper clips
- Table salt
- Gas flame
- Several light sources

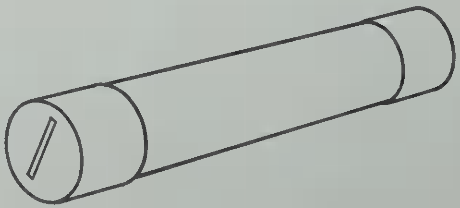
Procedures

A. Roll and tape a piece of construction paper to form a tube about 3cm in diameter.

B. Tape a 3cm x 3cm piece of diffraction grating over one end of the tube. Tape along the edges so that light can pass through the grating.

C. Tape two pieces of dark-colored construction paper over the other end of the tube so that a slit 1mm across is formed, as shown in Figure 12.25.

Figure 12.25.
Set-up for Procedures A-C.



D. Hold the spectroscope with the diffraction grating close to your eye.

Look through the slit at various light sources in the room, such as an incandescent light and a fluorescent light. Record your observations.

E. Record observations of a neon lamp if available.

F. You can analyze sunlight by looking at a white wall in bright sunlight.

CAUTION: Never look directly at the sun through your instrument.

G. Observe the light produced when chemicals are heated in a flame. To do this, straighten a paper clip and bend one end into the shape of a small loop. Tape the other end to a pencil or small stick. Moisten the loop and dip it into some table salt (sodium chloride). Place the loop in the flame of a gas burner and view through your spectroscope.

Other chemicals should be tested if available. A new loop should be used for each chemical tested. Record all results.

Interpretations

1. What evidence do you have to suggest that light from an incandescent bulb is composed of many colors?

2. Compare the light produced when the chemicals sodium and mercury (or neon) give off light. (A fluorescent light contains mercury vapor.)

3. How might an astronomer use a spectroscope?

THE SPECTROSCOPE

The spectroscope enables the astronomer to analyze light from the sun, the stars, and from other objects in the sky. The instrument can be used to look at the light given off when different chemical elements are heated to high temperatures. If the light is passed through a diffraction grating, it will separate into its different colors.

When heated, each element produces its own characteristic pattern as viewed through the spectroscope. Analysis of light from a star indicates which elements are present. This is true even when two or more elements are present in the star. In this way, the composition of stars billions of miles from Earth can be studied.

From such investigations, scientists have learned that the earth, our sun, and the other stars are all made of the same elements. The chemical composition of the sun and many other stars is about 75 percent hydrogen and 23 percent helium. Other elements make up the balance.

In Investigation 12.4 you learned that temperature can cause changes in the colors of substances. By spectroscopic analysis, information can also be gained concerning the temperatures of stars.

FOR FURTHER ACTIVITY

Design and carry out an experiment to test the effect of temperature on the color of a heated object.

TEACHER MATERIAL

INVESTIGATION 12.8: Building a Spectroscope

Materials

Transmission diffraction grating is a clear plastic sheet on which more than 13,000 grooves per inch have been scored. Light passing through the grating is "broken up," or diffracted, into the colors of the spectrum. (A roll of diffraction grating is not too expensive and can be purchased from many scientific supply companies.)

Incandescent, fluorescent, and (if available) neon or other gas-discharge tubes should be placed around the room for students to examine through the spectroscope.

Procedures

A. No comment.

B. Some students may tape the diffraction grating in position with the grooves running horizontally; this will make the spectroscope more difficult to use. If the spectrum appears above and below the slit, have the student loosen the tape and rotate the diffraction grating 90°.

C. For best results the slit should be as narrow as possible. It may have to be widened when viewing very dim sources.

D.-F. The spectra will vary as different types of light sources are viewed. See Interpretations, below.

G. Compounds of copper and lithium produce dramatic bright lines in the green (copper) and red (lithium)

regions of the spectrum. A darkened room helps in viewing these tests.

Interpretations

1. The hot filament of an incandescent lamp produces a continuous spectrum. An unbroken band of colors is seen on each side of the slit. The violet end of the spectrum is nearest the slit.

2. The fluorescent bulb produces a spectrum that is both continuous and a bright line spectrum. Two or three bright lines appear superimposed on the continuous spectrum in the violet, green, and yellow regions.

Neon produces bright red and orange lines. Sodium produces bright lines in the yellow region.

3. An astronomer can analyze and compare the spectra produced by stars as an aid to classification.

FOR FURTHER ACTIVITY

A small light bulb attached in series with a variable resistor to a 6-volt battery can be used to show the effects of temperature on a spectrum. At low amperage the spectrum should contain mostly red and orange. As the amperage is increased and the bulb burns more brightly, the blue end of the spectrum should be seen.

GALAXIES

As you look up at night it may seem that the stars are distributed rather evenly across the sky. With the aid of a telescope or binoculars you can see many more stars than you can with the unaided eye. Looking through these instruments also reveals that stars are not sprinkled evenly in space. Careful study with telescopes reveals that stars are concentrated in large groups called galaxies. Between the galaxies are vast expanses of space containing some dust and gas.

The stars you see belong to the galaxy of which Earth is a part--the Milky Way Galaxy. The sun is just one of more than a hundred billion stars in this galaxy.

It is impossible for man to step outside the Milky Way and see what our galaxy looks like from a distance. Similarly, a fish in a tank cannot tell what the tank would look like from outside. However, by examining other galaxies through telescopes, it is possible to make some reasonable guesses about the appearance and structure of our own.

With the most powerful telescope about one billion of the galaxies in the universe can be seen. Future telescopes will undoubtedly reveal many more. The visible galaxies are about one to two million light years apart.

TYPES OF GALAXIES

Astronomers have classified galaxies into three major types: spiral, elliptical, and irregular. The Andromeda Galaxy is shaped like a spiral, with arms curving out into space (Figure 12.26). About 80 percent of all galaxies that have been observed are spiral-shaped. A spiral galaxy rotates around a central axis. Stars, clouds of gas, and dust are distributed in the spiral arms, and also in the central portion (see Figures 12.27 and 12.28).

Figure 12.26.
The Andromeda Galaxy.

Figure 12.27.
Top view of a spiral galaxy.

Figure 12.28. Side view of a spiral galaxy.

Another type of galaxy may range in shape from spherical to oval. These are called elliptical galaxies (Figure 12.29). They are smaller and contain fewer stars than do spiral galaxies. Elliptical galaxies may contain from one million to ten billion stars but very little dust.

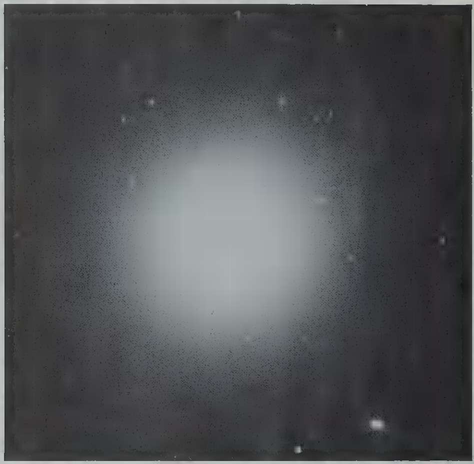


Figure 12.29.
Spherical and oval shaped galaxies.

The third major type is the irregular galaxy. As the name implies, these galaxies have no spiral arms, no concentration of stars in the central region, and no symmetrical shape. Only about three percent of all galaxies observed are irregular. Yet the two galaxies nearest to ours in space--the Clouds of Magellan--are of this type (Figure 12.30). They can be seen from the Southern Hemisphere and are large compared with the apparent size of the moon.

Figure 12.30.
The Clouds of Magellan.

Photographs of galaxies may make it appear that they are practically solid masses of stars. Actually, the stars within distant galaxies are as widely spaced as they are within our own galaxy. Thus a galaxy consists mainly of empty space. Between galaxies space is even more empty. Though hard to really appreciate, the emptiness of the universe is one of its main characteristics.

PROBLEMS

1. What do you think would be the appearance of star patterns in an elliptical galaxy as seen by an observer near:
   a) its center?
   b) its edge but still within it?

2. What do you think would be the appearance of star patterns in a spiral galaxy as seen by an observer near:
   a) its center?
   b) its edge but still within it?

3. What do you think would be the appearance of star patterns in an irregular galaxy as seen by an observer near:
   a) its center?
   b) its edge but still within it?

4. Figure 12.31 is a photograph of a large portion of our own galaxy, the Milky Way. The sun is one of the billions of stars in the Milky Way. What type of galaxy do you think the Milky Way is? Do you think that the sun is located in the central region or nearer the outer portion of the galaxy? Give reasons to support your answer based on the information contained in this section.

5. Which of these statements do you think is more accurate?

   a) "Last night a star in the Z Galaxy became a nova."

   b) "Last night a nova was observed in the Z Galaxy."

   Explain your choice.

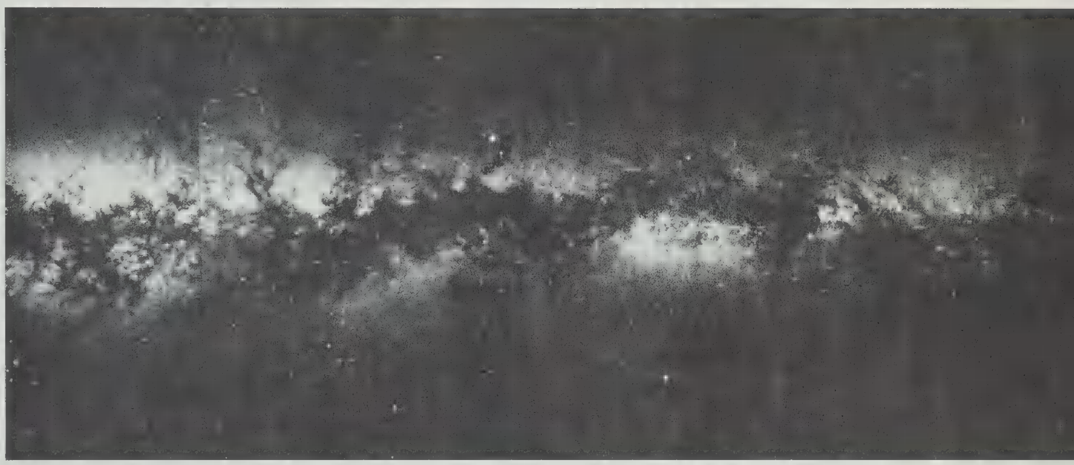


Figure 12.31. The Milky Way.

TEACHER
MATERIAL

GALAXIES

Stars are not distributed evenly throughout space, but occur in groups known as "galaxies." Most of space is empty.

Galaxies may be classified as spiral, elliptical, or irregular.

Virtually all celestial objects which are visible are parts of our own galaxy, the Milky Way.

The reading material and photographs are intended to give students background on the existence of galaxies and their characteristics. Problems 1-4 are intended to lead students to the conclusions that our star, the sun, is located in a galaxy, and that it is of the spiral type, and that our location is toward the edge of the Milky Way Galaxy. For this reason it is recommended that you not answer questions of the form, "What sort of galaxy are <u>we</u> in?" until members of the class have had an opportunity to think carefully about the problem themselves.

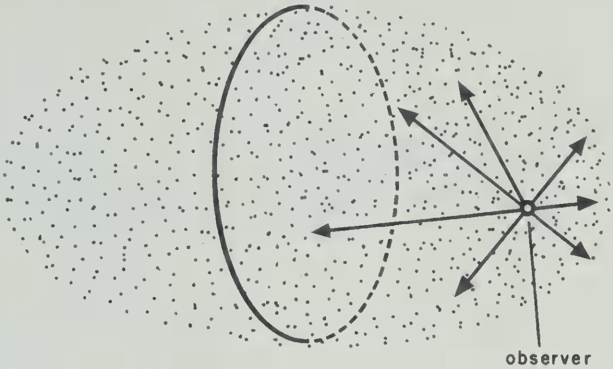
The Andromeda Galaxy is also known as M31, but not mentioned by this name in the text. The reason is that in Observation D.5, found in Appendix D, students are directed to look for "M31." Those who are able to locate this dim object may be able to associate Andromeda and M31 without being told of their identity.

PROBLEMS

1. a) An observer located near the center of an elliptical galaxy would probably see large numbers of stars regardless of the direction in which he looked.

b) An observer located near the edge of an elliptical galaxy would probably see large numbers of stars in one direction (looking toward the center of the galaxy) and few stars in the other (looking out of the galaxy). See Figure T-12.1.

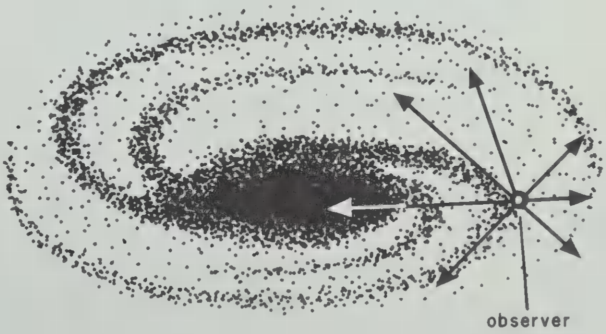
Figure T-12.1.



2. a) An observer located near the center of a spiral galaxy would probably see many stars in every direction. He might see particularly large numbers when looking out along the plane of the galactic disc.

b) An observer located near the edge of a spiral galaxy would probably see a heavy concentration of stars along a narrow band (toward the center of the galaxy) and fewer stars in other directions. See Figure T-12.2.

Figure T-12.2.



3. a) An observer located near the center of an irregular galaxy would probably see large numbers of stars in every direction, with heavier concentrations in some directions.

b) An observer located near the edge of an irregular galaxy would probably see large concentrations of stars in some directions and fewer stars in others, with no distinct pattern apparent.

4. Figure 12.31 most closely resembles the description of space as seen by an observer near the edge of a spiral galaxy. Students should be able to conclude that the sun could not be near the center of any type of galaxy. If it were, the high density of stars would not be restricted to a path like the Milky Way.

From the central region of an elliptical or spiral galaxy, many stars would be visible in all directions. Although the density of stars might not be so uniform for an irregular galaxy, still there would be no well-defined region in which the stars are concentrated.

From the portion of the Milky Way shown in Figure 12.31 students could infer that our galaxy is a spiral, based on the concentration of stars in a band. Some students may say that the Milky Way is <u>probably</u> a spiral, since 80 percent of the galaxies observed are spiral. This, too, shows good thinking. Some may say that no judgment can be made since the photograph includes a relatively small region of space. Encourage all answers, but (more importantly) ask students to support their answers with logical arguments.

After reviewing Problems 1-4 with the students, you may want to discuss the currently accepted model of our galaxy:

The Milky Way is a huge collection of stars--some 100 billion of them--in a group shaped like a fried egg. These stars are held together by gravity. When one looks toward the rim of the Milky Way (see the arrows labeled A in Figure T-12.3), there is a path, or band, in which more stars are concentrated. When one looks in other directions (B arrows

in Figure T-12.3), there are fewer stars and the sky appears darker.

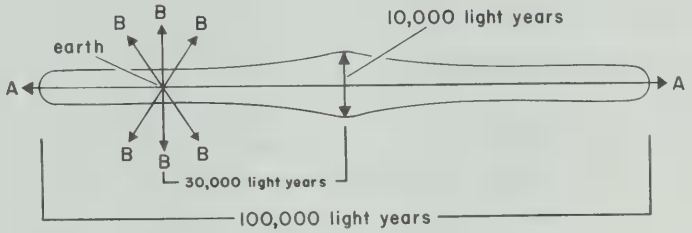


Figure T-12.3. Cross section view of the Milky Way Galaxy.

5. The problem is intended to focus attention on the fact that light arriving from far off parts of the universe bears with it information concerning events which happened in the distant past. If the nova in question occurred in, say, the Andromeda Galaxy, it would take two million years for light signaling the event to reach Earth. Therefore it is preferable to say that the event was observed last night (the b answer) than to say it occurred last night.

NEBULAE

One of the first men to look at the Milky Way through a telescope was the Italian scientist, Galileo. In 1610 he wrote that the telescope enabled him to see individual stars instead of a hazy bright band.

William Herschel, the English astronomer who discovered the planet Uranus in 1781, also observed that stars are more concentrated along a line through the center of the Milky Way. Herschel noted too that a hazy glow could be seen among the stars on both sides of the line through the center of our galaxy.

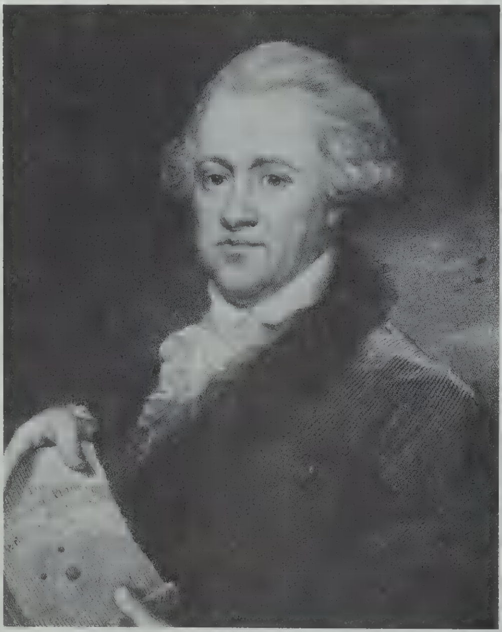


Figure 12.32. Sir William Herschel (1738-1822)

A cloud of gas or dust that appears as a hazy spot in the telescope is called a nebula (neb u la: plural, nebulae). Nebulae may be divided into two main groups: bright nebulae and dark nebulae. Bright nebulae can be seen for one of two

reasons: Either they give off their own light, or they reflect light from nearby stars. Dark nebulae neither reflect nor give off light. They are visible because they block out light from bright objects behind them. A great deal of interstellar gas and dust is spread through our galaxy. Most of it is located near the center of the galaxy (from rim to rim) rather than being spread evenly throughout the space between the stars (see Figure 12.33). The density of this material is very low--far lower than that of the best vacuums man has created in the laboratory.

Figure 12.33. Most of the interstellar gas and dust in our galaxy is located in the shaded area.

PROBLEMS

Figure 12.34.

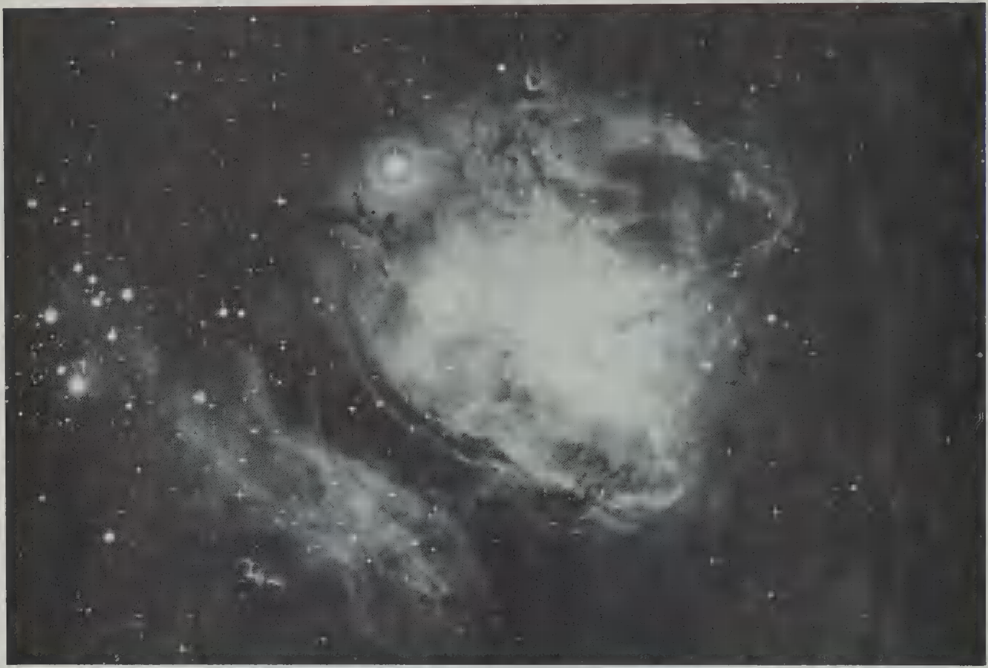


Figure 12.35.

Figure 12.36.

Figures 12.34, 12.35, and 12.36 are photographs of nebulae. One nebula is made of dust particles. One is an exploded star. And one is a glowing mass of gas. Recall that the types of nebulae are bright and dark.

1. Identify the type of nebula shown in each figure.

2. Which figure do you think shows an exploded star? Give reasons for your answer.

3. Which nebula do you believe has the lowest temperature? Give reasons for your answer.

TEACHER MATERIAL

NEBULAE

PROBLEMS

1. Figure 12.34 is a dark nebula. This photograph shows the "Horsehead" Nebula in Orion.

Figure 12.35 is a bright nebula. It is called "The Lagoon" and is in the constellation Sagittarius.

Figure 12.36 is also a bright nebula. It is the "Crab" Nebula in Taurus.

2. Figure 12.36 shows the remains of a supernova seen and recorded by the Chinese in the year 1054 A.D. Students may suggest that the bright filaments seen in Figure 12.36 look like jets of gas from an explosion. The gas cloud in Figure 12.35 has no such distinctive shape. The nebula in Figure 12.34 is dark and resembles a cloud rather than an explosion.

3. The "Horsehead" Nebula (Figure 12.34) has the lowest temperature because the matter in it is not hot enough to give off light. In Investigation 12.4 students found that the hotter an object is, the more light it gives off.

THE FORMATION OF THE UNIVERSE

Until the invention of the telescope, the term universe was used to include not much more than the Milky Way. No one realized just how much is "out there" or how relatively small is the space the sun and its surrounding planets occupy. Scientists have proposed several models to account for the beginning of the universe. The "Big Bang," the "Steady State," and the "Pulsating Universe" are the names given to three such models. It is impossible to present complete descriptions of the models here; to do so would fill many books the size of this one. However, the basic ideas in each of the three models are presented for your consideration.

1. According to the Big Bang model, some 10 to 15 billion years ago all matter in the universe existed in a single compact mass. As particles of matter attracted one another (by gravity) the mass became more and more dense. The resulting pressure at the center of the mass produced extremely high temperatures. In time the temperature rose so high that a huge explosion occurred. The "big bang" forced the matter out in all directions at tremendous speeds. During the explosion, all the chemical elements were formed. As matter continued to move out from the explosion, some condensed into clouds of gas and dust; these eventually formed the galaxies and stars. The Big Bang model predicts that matter--most of it now in the form of galaxies--will continue to move away from the original site of the explosion.

2. The Pulsating Universe model also pictures the universe beginning with a great explosion and expansion of matter. However, this model predicts that at some time, billions of years after the explosion, gravitational attraction between galaxies will cause them to stop speeding away from each other and then to rush inward again. They will become a compact mass, then explode again, and the cycle will be repeated.

3. The Steady State model suggests that the universe has always existed in the form we see today. As stars and galaxies move out of our sight, new matter is formed to replace that which has disappeared. In other words, the density of matter in the universe remains fairly constant, and the distribution of galaxies (matter) is relatively unchanging.

These models have been the basis of discussion among scientists for many years. As you know, the value of a model depends upon how well it explains observations that relate to it. It is impossible to prove that any of the models is correct. Indeed, few (if any) of the models man proposes to explain nature can be said to be proved correct. No one knows how future observations with new instruments will relate to a given model.

It is sometimes possible to show that a model is in error. This is the case when the model does not explain a certain observation. Then it must be revised or discarded.

PROBLEMS

1. The following is a brief list of observations scientists have made about the universe. Discuss them in class and decide whether the observations support (not prove) or contradict each model.

Observation A: All the galaxies seem to be moving away from each other, just as points on a balloon move apart as the balloon is inflated.

Observation B: Some galaxies appear to be moving away from the center of the universe so fast that the gravitational attraction of the rest of the universe will never be able to stop them. (Rockets launched into space from the earth must reach a speed great enough to overcome, or escape, the gravitational pull of the earth. Such a speed is called escape velocity.)

Observation C: Astronomers have detected sources of energy more than one billion light years away. They produce

energy by some method completely unknown on Earth. No nearby galaxy seems to produce energy in this way. Light that reaches Earth from a body one billion light years away was produced by a process that occurred one billion years ago. Therefore, scientists have suggested that the energy-producing process which occurred in the universe long ago is different from those going on now.

Observation D: In the explosion of an atomic or hydrogen bomb, matter is converted (changed) to energy. The sun's energy is produced by a process similar to that in a hydrogen bomb. In the laboratory, scientists have also succeeded in converting light energy to matter.

2. Which model provides the best basis for an explanation of the origin of the universe?

TEACHER
MATERIAL

THE FORMATION OF THE UNIVERSE

The three models relating to the origin of the universe are necessarily brief and do not describe all facets of the models. Also, some of the more sophisticated concepts built into the models are beyond the scope of this book. Library research on the models should help interested students with Problem 1.

PROBLEMS

1. Observation A: All three models can account for the movement of the galaxies away from each other. The galaxies should move away from a common point of origin according to the Big Bang model. The Pulsating Universe model contends that such movement will stop at some time and reverse itself. The Steady State model proposes that galaxies that move out of sight are replaced by "new" matter formed from energy in the universe. The energy is supplied by radiation from older galaxies.

Observation B: Some astronomers have calculated that many galaxies are moving at a speed great enough to overcome the gravitational attraction of the other galaxies in the universe. These calculations are based on estimates of the masses of known galaxies, the distances between the galaxies, and velocities of the galaxies in relation to each other. If these calculations are correct, the Pulsating Universe model must be rejected.

Observation C: Quasars are distant bodies that produce light energy in unknown ways. If this process of energy production is unique to a time more than one billion years ago, then the universe must be changing and the Steady State model must also be changed or discarded.

Observation D: The ability to produce matter from energy in the laboratory suggests that a similar process in nature could replace "lost" matter in the universe--thus lending support to the Steady State model.

2. Students will probably want to press for a conclusion that completely accepts or rejects each model. Eventually, however, the class discussion should stress the value of a model in helping man to understand something that cannot be directly observed, rather than the "correctness" of one model or another.

INQUIRY DEMONSTRATION: Distances Between the Sun and the Planets

This demonstration is designed to give students an appreciation for the relative size of the solar system. For best results it should be done out of doors and close to the time the class is discussing formation of the solar system which follows immediately in the text.

Materials

Kite string (about 100m)
Meter stick
Towel tubes (toilet tissue tube, etc.)
Knife

Procedures

A. (To be done before the class meets.) Split the end of a tube with the knife to a depth of 2cm. Tie one end of the ball of string to the middle of the tube. Pull out a length approximately 36cm long and cut the string. Wind the string around the tube and tuck the loose end in the split end of the tube. Label the other end of the tube "Mercury, #1." At a scale 1cm = one million miles, the string represents the average distance of Mercury from the sun.

B. Repeat Procedure A cutting appropriate lengths of string to represent distance from the sun for the remaining planets. Label the tubes "Venus, #2" etc. When finished place all the tubes in a box and close the lid. See Figure T-12.4 for actual distances and scale distances.

PLANET	AVERAGE DISTANCE FROM SUN IN MILES	STRING LENGTH
Mercury	36 million	36cm
Venus	67 million	67cm
Earth	93 million	93cm
Mars	142 million	1.42m
Jupiter	483 million	4.83m
Saturn	886 million	8.86m
Uranus	1787 million	17.87m
Neptune	2790 million	27.90m
Pluto	3675 million	36.75m

Figure T-12.4.

C. Before going outside to conduct the demonstration, select ten students and have them draw or select numbers from 1 to 10. Make sure each of the students knows (and remembers) his number.

D. Take the class (and the closed box of tubes) outside to an area at least 40 meters at its longest dimension. Call for student number ten. He is to represent the sun. Tell the class that they are going to construct a miniature solar system and that the other nine students will represent planets.

E. Call for student number one and announce that he is to represent the planet Mercury. You may give as much (or little) information about the planet as you feel appropriate. Hand him the "Mercury" tube and direct him to give the loose end of the string to student ten (the "sun"). Allow him to unwind his string to its full length. Tell the class of the scale to which the miniature solar system will be constructed.

F. Give the remaining eight students their strings, each in turn, discussing each planet as you do so. When completed, ask the class to study the dimensions of the system.

QUESTIONS FOR DISCUSSION

1. The sun has a diameter of about 860,000 miles. How large would it be on this scale? (8.6mm) How large would the earth be? (approximately .08mm)

2. The moon is about 240,000 miles (average distance) from the Earth. Discuss the "length" of a trip to the moon compared to a trip to other planets.

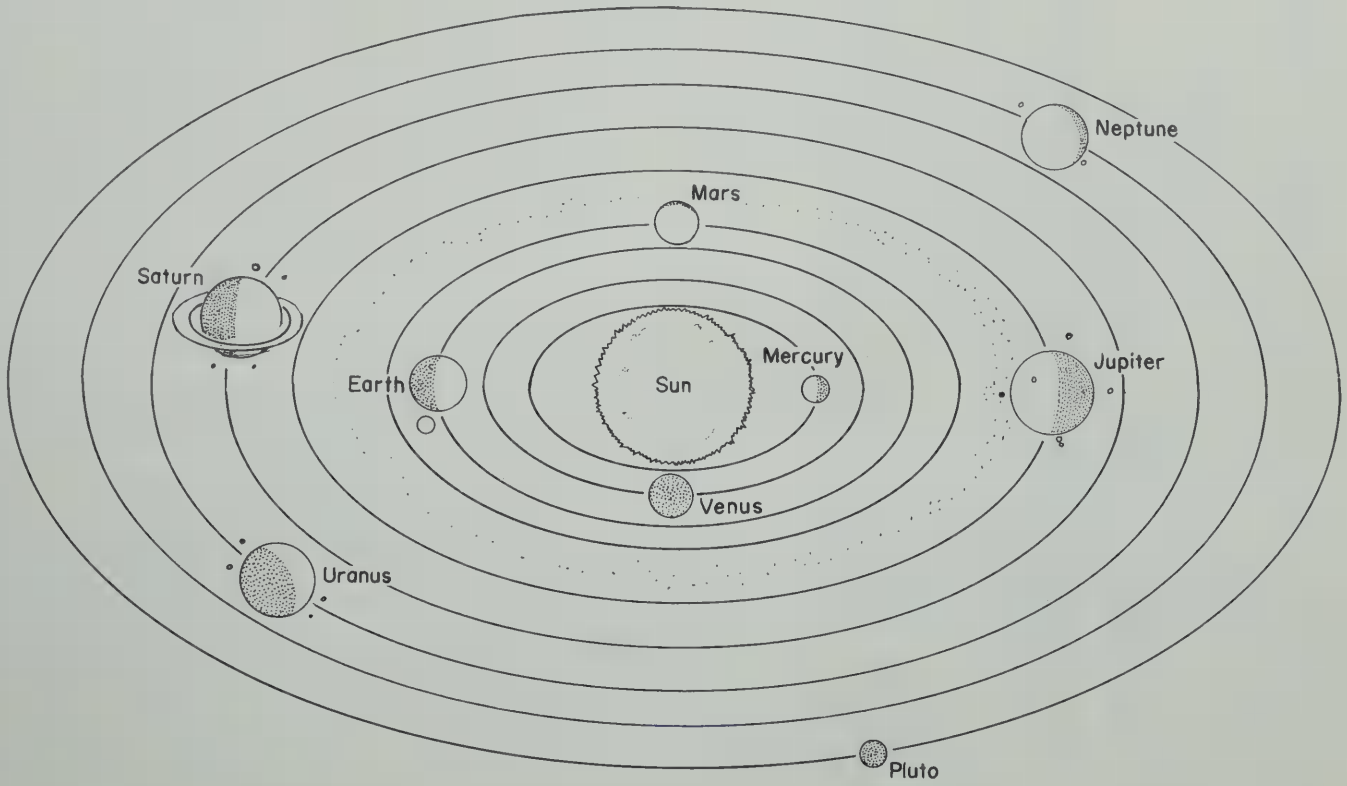
THE FORMATION OF THE SOLAR SYSTEM

Models have also been proposed to account for the origin of the solar system.

Before gaining wide acceptance, a model has to account for all that is known about the subject it deals with--in this case, the solar system.

What is known about our solar system? First, it consists of the sun, nine planets and their thirty-two moons. Also there are thousands of asteroids, comets, and meteors, and a great deal of dust and gas. The sun occupies a central position in this system. The planets circle around the sun in the same direction, and their paths are generally in the same plane (Figure 12.37). The sun, itself, is moving; it completes a rotation on its axis about every twenty-five days.

Figure 12.37. The solar system, showing the planets in order of distance from the sun. This drawing is not to scale. See Figures 12.37b for scale of sizes.



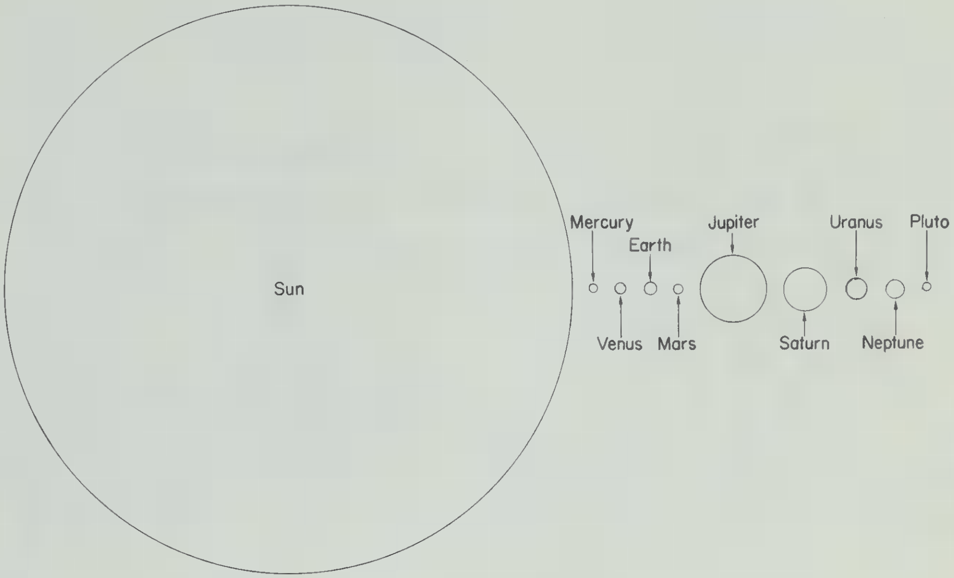


Figure 12.37b. Sizes of the sun and the planets, to scale.

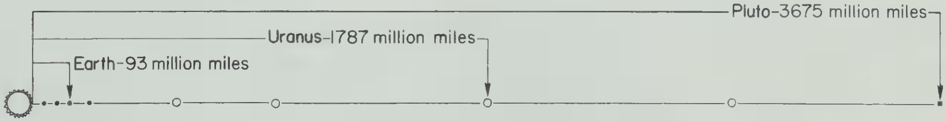


Figure 12.37c. Distance between sun and planets, to scale.

The sun is by far the largest member of the solar system. The smaller planets are Mercury, Venus, Earth, Mars and Pluto. These are dense and compact compared with the large planets--Jupiter, Saturn, Uranus, and Neptune. The solar system is estimated to be about five billion years old.

When men believed that a flat Earth was the center of the universe, early ideas about the origin of the solar system made sense. In modern times, several models have been accepted until new evidence caused them to be revised or discarded.

In the middle of the 18th Century, the German philosopher Immanuel Kant suggested that the entire solar system developed from an enormous cloud of gas. A French scientist, Pierre Laplace, was thinking along similar lines. The Nebular Hypothesis, as their model came to be called, assumes that the cloud of gas was rotating. Gradually, as it condensed, or became smaller and more compact, the cloud became hotter and the speed of rotation increased. Finally, this glowing mass cast out rings of gas. The central mass became the sun, and the rings cooled and condensed to form the planets.

One serious weakness in the Nebular Hypothesis is that it fails to account for the slow rotation of the sun. In 1900 two American scientists, Chamberlain and Moulton, pointed out another fault in the model. They offered convincing arguments that a hot gas would not condense to form planets but would move out into space.

Chamberlain and Moulton proposed a different model for the formation of the solar system. They suggested that a star once passed so close to the sun that the star's force of gravity pulled some material away from the sun. They proposed that ten bands of material were pulled out. These remained in orbit around the sun and condensed through thousands of years. Eight became planets. (This model was developed before the discovery of Pluto.) One band never fully condensed, and it became the belt of asteroids--thousands of small rocky bodies circling mainly between the paths of Mars and Jupiter. The tenth band was proposed to account for an undiscovered planet suspected to be orbiting beyond Neptune.

However, this model also has flaws: The chances that two stars would pass so close together are very slight. To illustrate: Suppose you left the United States in a rowboat heading for Europe, and an Englishman set out in a similar boat heading for America. The two boats would have a better chance of meeting in the ocean than would the two stars in the vastness of space.

Several years later, other scientists raised another objection. They could find no reason to suppose that the bands of material called for in the model would condense to become planets.

The Nebular Hypothesis of Kant and Laplace has been revived recently with some major changes. In addition to the stars, clouds of dust are scattered through the universe. The revised Nebular Hypothesis is called the Dust Cloud Theory. According to this model, planets are formed when a slowly spinning cloud of gas and dust condenses. If the dust cloud is rotating rapidly, the material condenses into two or more stars. And if the cloud is not spinning at all, then a single, large star is formed. But if the speed of rotation is moderate, whirlpool regions, called eddies, may develop (Figure 12.38).

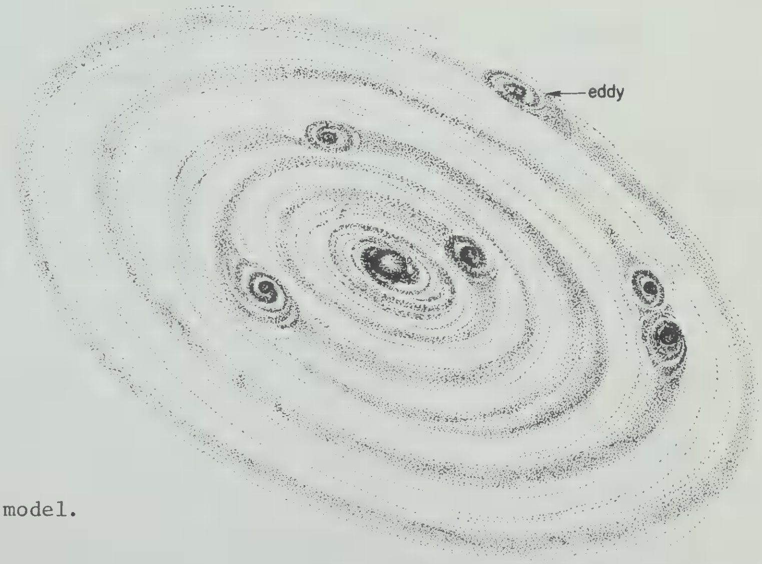


Figure 12.38.
The Dust Cloud model.

The whirling gas and dust are pulled together by gravity, and the eddies eventually become planets and moons.

Gravity would cause the greatest concentration of material to occur at the center of the whole cloud. As the material becomes more concentrated near the center, collisions between particles are more frequent and more violent. Finally collisions occur often enough and with enough force to start a nuclear reaction, and the central portion becomes a star, such as our sun.

About a third of the visible stars are multiple. According to the model, these would have been formed from rapidly spinning clouds of gas and dust. It is reasonable to suppose that other clouds, spinning more slowly, have produced star-planet systems. This has lead astronomers to predict that there may be many solar systems in the Milky Way and in other galaxies too.

In summary, the Dust Cloud Model accounts for the properties of the solar system in the following ways:

1. Observation: All members of the solar system move around the sun in the same direction and in about the same plane (Figure 12.37).

Model: According to the model, the dust cloud was rotating, and the spinning should make it spread out in a plane.

2. Observation: There are many relatively small members of the system, such as asteroids, comets, and meteors.

Model: These probably resulted from the small eddies that formed in the rotating mass.

3. Observation: The planets are relatively far apart, and many of the planets have moons.

Model: A planet and its moons (if any) would form from an eddy that gathered material from a large region.

4. Observation: The sun is in the center of the solar system, and it contains much more material than is found in all the other bodies in the system combined.

Model: Gravity should concentrate the largest amount of material at the center of the system, and the nuclear reaction should start where the pressure is greatest.

The Dust Cloud Model does not satisfactorily answer all questions about the formation of the solar system, but it is now the most widely accepted model. Like any model, it is subject to change when new evidence is presented that does not fit existing ideas.

TEACHER
MATERIAL

THE FORMATION OF THE SOLAR SYSTEM

In this section students are presented with two models concerning the origin of the solar system: the Nebular, or Dust Cloud, Model; and the Two-Star Model. Interestingly, the Nebular Hypothesis was proposed in the last half of the 18th Century but was generally discarded by the beginning of the 20th Century. For the next forty years or so the Two-Star Theory seemed more plausible, until several inconsistencies were revealed.

Since 1950 the older model--with some important revisions--has been more commonly accepted.

One of the important concepts for students in this section is that a model should explain the facts as we currently understand them to be. With the addition of new ideas or new interpretations, the model must be either revised or rejected. In the latter case, a new model has to be developed.

New evidence was introduced to demonstrate that the material pulled out of one star by a chance encounter with another (by either a close passing, a side-swipe, or an actual collision) would not condense into planets. Instead, the material would escape into space or fall back into the sun. This, together with the improbability of the encounter, caused the Two-Star Theory to be abandoned.

In the Dust Cloud Model, the earlier Nebular Hypothesis has been revised to include the presence of smaller whirlpools within the enormous mass of rotating dust. After these condensed to become the planets and satellites, the remaining dust was forced outward by radiation from the sun. The larger planets were farther from the sun, so they were affected less by this pressure. As a result, Jupiter, Saturn, Uranus, and Neptune retained more low-density material.

The forming of a solar system is now thought to be a fairly common occurrence. Given the fact that there are about 100 billion stars in the Milky Way Galaxy, the probability is very high that numerous such systems exist. Some of these might support life forms.

Finally, if the billions of other galaxies in the universe are included, the probability that we are not alone becomes significant. You might want to discuss this likelihood with your students.

PAST, PRESENT AND FUTURE

The three photographs in **Figure 12.39** show volcanic activity in the North Atlantic Ocean near Iceland. How would you arrange the photographs to show a correct sequence of activity? What additional information would be useful in arranging the scenes in their proper order? What do you think a photograph of the area taken today would look like? What would a future photograph probably show?

The questions asked are difficult ones. However, with some additional information and a knowledge of earth processes, answers are possible.

A study of the earth, its position in space, its life, its weather, its structure and its oceans presents the curious observer with similar kinds of problems.

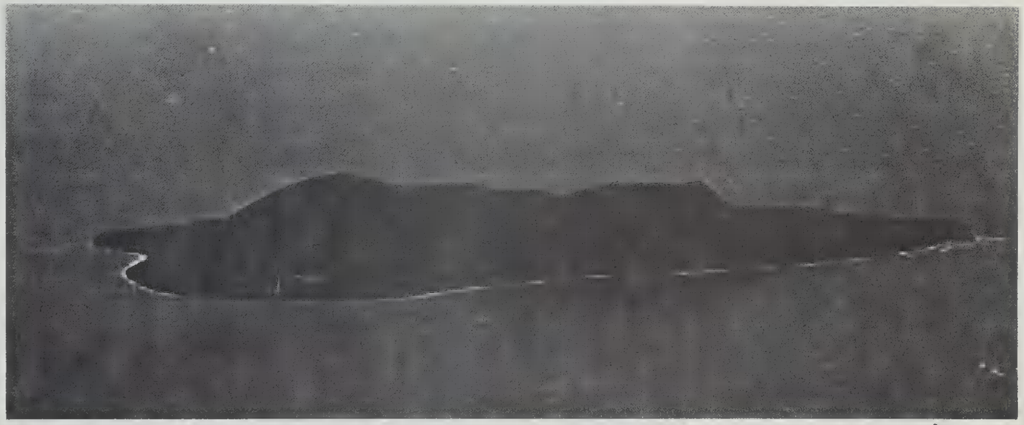
What the casual observer sees of the earth today is in many ways like a stop-action photo taken during a very long sequence of change. Taken alone, such a view provides little insight into the vast scale of interactions that shape the earth's history. Careful observation can provide you with other "photos" in the sequence. A fossil footprint may bring to mind a stop-action image of a previous form of life. The size of crystals in a rock may indicate the rate at which the rock cooled.

In some areas of study there are many "photographs" to help in piecing together the sequence--in others there are few.

After gaining a knowledge of the natural processes that produce a sequence of change you can even make logical predictions of future change.

It is hoped that your study in this course will help you to place your present view of the earth in its proper place in the puzzle. And, perhaps more importantly, it will help you to judge the total effect on the earth of changes that man proposes.

a



b

Figure 12.39.
Surtsey:
Three views.

c

APPENDIX A: Metric-English Units of Length

English to Metric

1 mile	=	1.6094	kilometers
1 yard	=	0.9144	meter
1 foot	=	0.3048	meter
1 inch	=	2.5400	centimeters

Metric to English

1 kilometer	=	0.6214	mile
1 meter	=	1.0936	yards
1 centimeter	=	0.3937	inch
1 millimeter	=	0.03937	inch

Metric to Metric

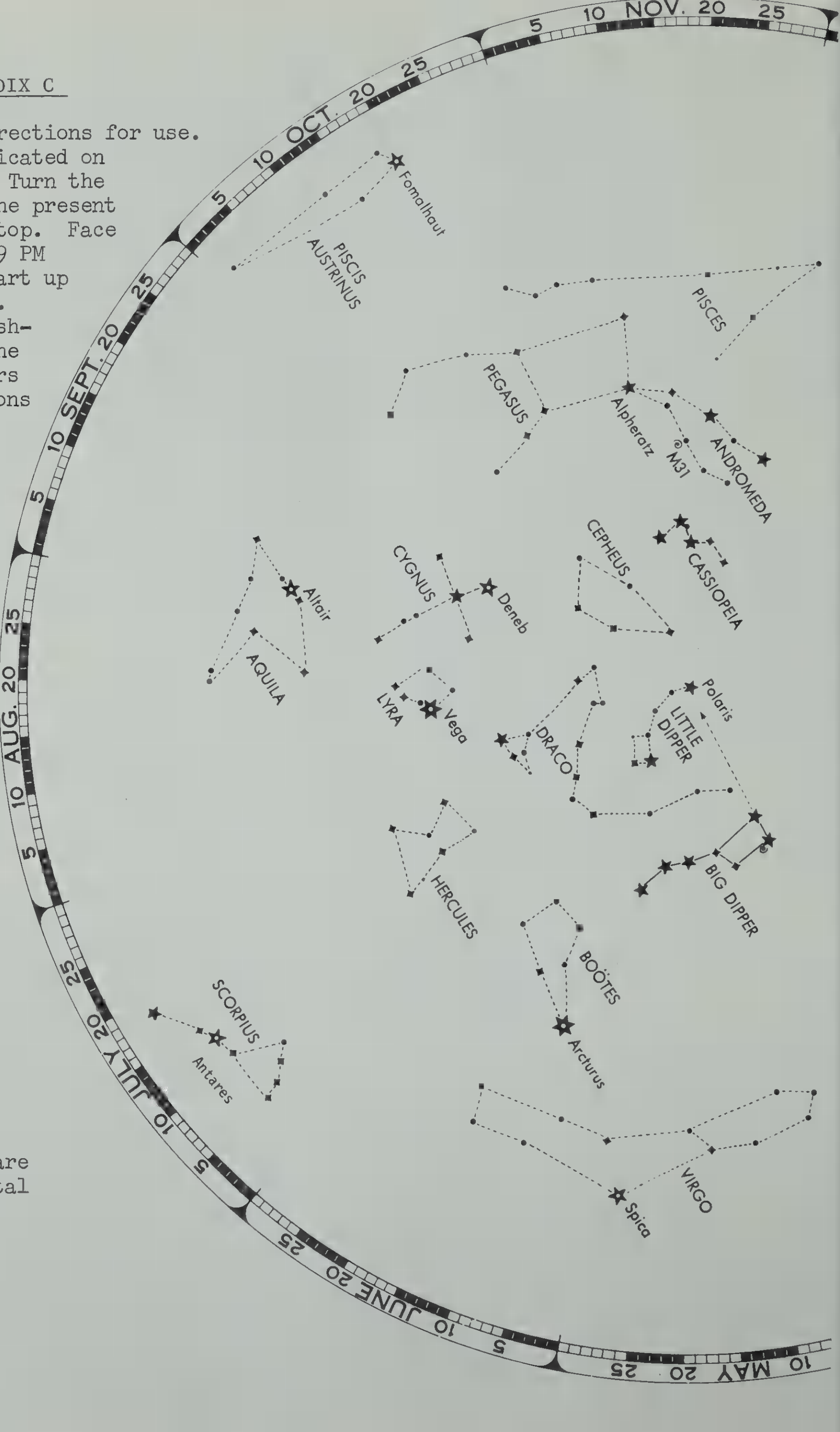
1 kilometer	=	1000 meters
1 meter	=	100 centimeters
1 centimeter	=	10 millimeters
1 meter	=	1 million microns
1 meter	=	1000 millimeters

APPENDIX B: Fahrenheit-Celsius Conversion Scale

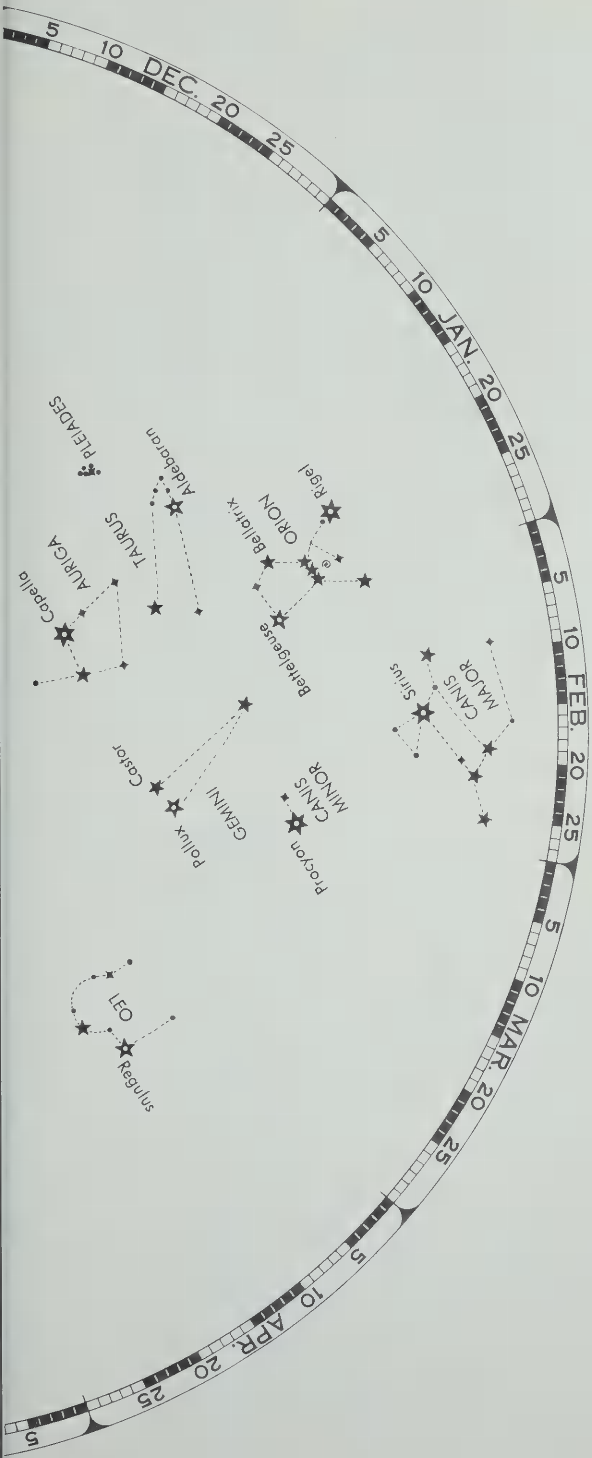
°Fahrenheit	°Celsius
122	50
113	45
104	40
95	35
86	30
77	25
68	20
59	15
50	10
41	5
32	0
23	-5
14	-10
5	-15
-4	-20

APPENDIX C

STAR CHART: Directions for use. Assemble as indicated on opposite page. Turn the chart so that the present date is at the top. Face north at about 9 PM and hold the chart up at arm's length. Use a small flash-light to read the chart. The stars and constellations will be in the same positions in the sky and on the chart.



KEY:
Constellations are labeled in capital letters.



Cut out this portion of the chart and fit it to the straight edge of the portion on the opposite page. Fasten in place with transparent tape.

APPENDIX D: Star Observations

OBSERVATION D.1: Locating Fomalhaut

Fomalhaut is one of the stars used by navigators to help determine location. It is the eighteenth brightest of all the stars in the sky. Fomalhaut is the thirteenth brightest star seen from most parts of North America. It may be seen between mid-October and mid-November. The following are the best times for viewing:

October 20	9:00 p.m.
October 27	8:32 p.m.
November 4	8:00 p.m.
November 11	7:32 p.m.
November 19	7:00 p.m.

Procedures

A. Determine the time for viewing on the date you select. These times are given for locating the star above the southern horizon. Fomalhaut can be seen earlier than indicated by looking south-easterly. It can also be seen later in the south-west sky.

B. Face south and look up about one fourth of the way from the horizon toward straight up. Look for the brightest star in that part of the sky. This is Fomalhaut. Record the color and appearance of the star.

TEACHER MATERIAL

OBSERVATION D.1: Locating Fomalhaut

Because of its position low in the southern sky, Fomalhaut may be difficult to observe from northerly locations. Position of the star is indicated on the star chart, Appendix C.

Procedures

A. No comment.

B. Fomalhaut appears blue-white or white. It may be reported that the star was "twinkling." Stars appear to twinkle due to the movement of air between the viewer and the star. When the viewer looks at the sky directly overhead, he is looking through less air than when he looks at the sky near the horizon. Therefore stars near the horizon seem to twinkle, while those overhead do not.

OBSERVATION D.2: Times of Rising

In Investigation 2.6 you observed star groups that could be seen in all seasons. The circumpolar constellations swing around Polaris throughout the year; they never rise or set.

This is not true of other constellations. They cannot be seen every evening of the year. These stars appear to rise and set much as the sun and the moon do.

You can check how much earlier or later a star rises from one evening to the next.

This activity may be performed at any time of the year. However it is closely related to Investigations 2.6 and 3.2.

Procedures

A. Sometime after dark, face east and look at the sky near the horizon. Select a star you can easily find again.

B. Make a note of some object (a tall tree, the point of a roof, a telephone pole) that you can line up with the star. Move until the star seems to rest on the edge or point of the object. Drive a small stake into the ground where you are standing, and note the exact time. See Figure D.1.

C. Return to the stake a few minutes earlier on the following evening. Be sure you are standing in the same position and sight the same star over the object.

D. Note the exact time at which the star appears to rest on the same object.

Interpretations

1. Did you see the star in the same position earlier or was it later on the second evening?

2. How much earlier or later was it?

3. How much difference will there be in one month if the same amount of change takes place each day?

4. If the same amount of change occurred each day for a year, what would be the total <u>annual</u> (yearly) change?

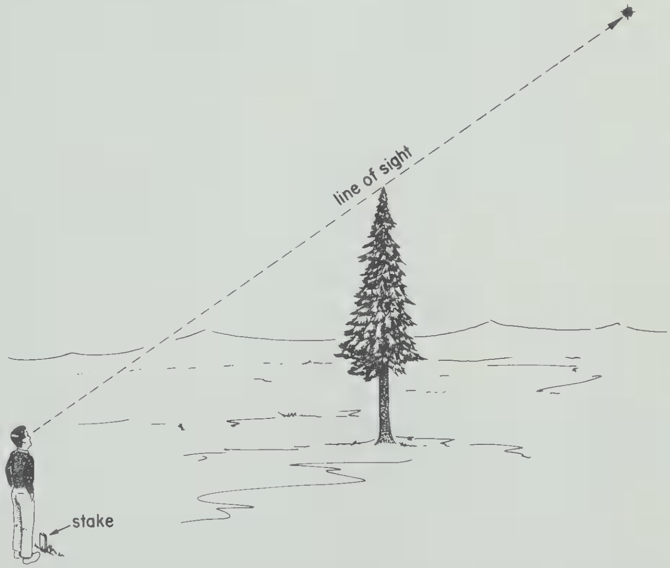


Figure D.1.

<u>Procedures</u> (continued)

E. Check the same star a week or more after you first observed it. Note the time at which it appears in

the same location as on the first night. Find the average number of minutes change in time per night.

Interpretations

5. What advantage might there be in spacing out your observations rather than looking at the star on two successive nights?

TEACHER MATERIAL

OBSERVATION D.2: Times of Rising

This activity provides background for Investigation 3.2. Students are asked to observe the position of a star on two successive evenings and record the times.

Procedures

A.-D. No comment.

Interpretations

1. On the second evening, stars are in the same positions earlier.

2. If this is done accurately, the students should note that stars return to the same positions four minutes earlier each evening.

3. In a month the difference amounts to 120 minutes, or two hours.

4. In one year, the difference is 24 hours; therefore the stars will return to the same positions they occupied a year before.

Procedures (continued)

E. The average difference in rising time will be equal to the total number of minutes difference divided by the number of days between observations.

Interpretations

5. Very slight differences in eye location could cause a minute or more error in fixing the time of the star. If the observations are spaced out by several days, any error in sighting will be divided and thus minimized. Qualitatively, the large difference in rising time over, say, a month will make it apparent that stars are rising earlier even if the exact amount of time cannot be determined.

Constellations

If you had a map of the world in front of you and were asked to find Addis Ababa, you might need quite a bit of time. However, if you were told that the city is in the continent of Africa, in Ethiopia, and situated approximately 9° North Latitude and 38° East Longitude, you could find it easily. Similarly, it is easier to locate a star if you are told which large group, or constellation, it is in and are given some instruction in identifying constellations.

There are 88 constellations. The names of the constellations have come down to us from several ancient civilizations. Some were named for the objects they seemed to resemble. Others were named in honor of a god or hero. Not all constellations are visible from any one location. With a map of the sky, you can determine which are visible from your latitude.

OBSERVATION D.3: Locating the Great Square of Pegasus (November-December)

Procedures

A. The Great Square of Pegasus can best be seen between November 1 and the end of the year. Consult Figure D.2 for the suggested viewing times. You can use this table to obtain the approximate time for any evening in the three-month period.

November 1	9:00 p.m.
November 8	8:32 p.m.
November 16	8:00 p.m.
November 23	7:32 p.m.
December 1	7:00 p.m.
December 8	6:32 p.m.

Figure D.2.

B. At the proper time on the date you select, face south. Look up rather high, but not overhead. Find four stars that mark out an approximate square. This is part of the constellation Pegasus the Horse (Figure D.3). The rest of the constellation is difficult to see.

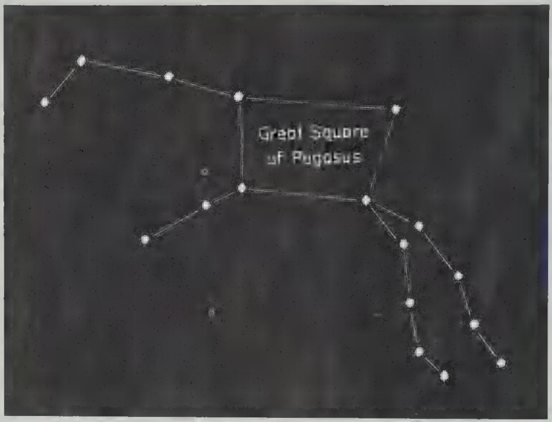


Figure D.3.

Interpretations

1. Which of the four stars in the Great Square appears dimmest? Do the stars twinkle?

TEACHER MATERIAL

OBSERVATION D.3: Locating the Great Square of Pegasus (November-December)

Procedures

A.-B. The Great Square of Pegasus is an easy group of stars to locate high in the southern autumn sky. In the table, students may be able to see that the best viewing time occurs four minutes earlier each succeeding evening.

Interpretations

1. The dimmest star in the Great Square is in the southeast (lower left) corner. These stars do not appear to twinkle much, since they are high in the sky.

OBSERVATION D.4: The Sun Stands Still (December - January)

Your first gnomon record was probably made on or near September 22. At that time days and nights were of equal lengths. Such a time is called an equinox, from the Latin meaning "equal night." A solstice, from the Latin "sun stands still," occurs on or about December 22. At this time nights are as long as they will become, and days will begin to lengthen.

Your work with globes and light sources may have suggested that changes in lengths of daylight hours are related to the tilt of the earth's axis. In this observation you will compare gnomon records made at the equinox and at the solstice. By doing so you should be able to measure the degrees of change in tilt of the earth's axis between the two dates.

Materials (per team)

Outdoor gnomon record for a date close to December 22
Globe with indoor gnomon
Protractor
Centimeter rule
File card

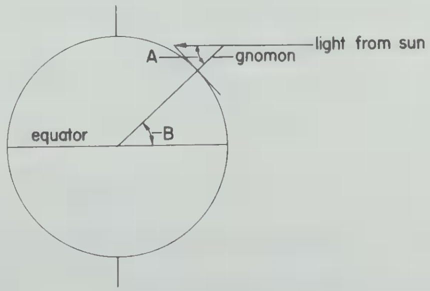


Figure D.4. Earth axis perpendicular to light rays from sun; gnomon angle (A) equals latitude angle (B).

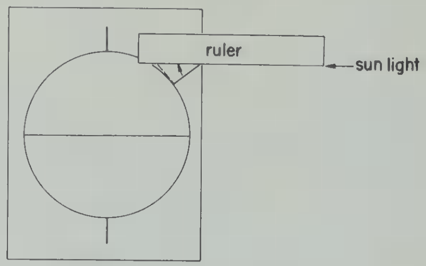
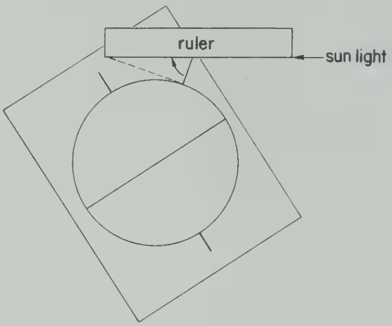


Figure D.5.



Procedures

A. Examine Figure D.4. It shows that the angle at the top of a gnomon is equal to the latitude of its location. But this is true only when rays of light from the sun are perpendicular to the axis of the Earth. Why is this so? There are two ways of looking at the matter.

B. Use Figure D.4. as a model. Place a straight edge along the line representing the light ray that is just above the top of the gnomon.

Now represent the tilting of the Earth's axis by holding the straight edge stationary but rotating the diagram counter-clockwise. (See Figure D.5.)

Interpretations

1. If the pole tilts away from the sun, will the latitude of an observer change?

2. If the pole tilts away from the sun, will the gnomon angle change?

3. If the angle changes, will it increase or decrease?

Procedures (continued)

C. Procedure B showed how changing the tilt of the axis causes the gnomon angle to change. However it was in one way inaccurate. The point in the sky at which the axis is directed does not change. From Investigation 3.1 you know that throughout the year the axis of the Earth is always directed toward the same point in space.

The second way of showing how the amount of tilt can be measured involves use of the globe.

The very first gnomon investigation you performed resulted in a nearly straight shadow line. At the time you performed that investigation, days and nights were of approximately equal length. Set up your globe to match those conditions. Find out if the rays of light are perpendicular to the axis.

Interpretations

4. Can the conditions of Procedure C be met (days and nights of equal length, gnomon shadow line straight) with rays not perpendicular to the axis?

5. Is there a time when the sun's rays are perpendicular to the earth's axis?

Procedures (continued)

D. Set your model globe in a position to represent all the various observations that can be made at this time of year. The axis must be directed toward Polaris. In the Northern Hemisphere nights must be long, and days short. Gnomon shadow lines must be curved. Your globe should be set up as shown in the December position (Figure D.6).

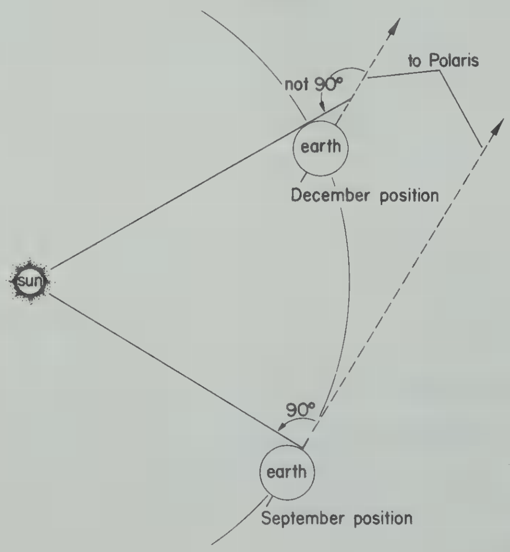


Figure D.6. In the September position, days and nights are of equal length and the gnomon shadow line is straight. This can be explained if the tilt angle does not incline the north pole toward or away from the sun.
In the December position, days are short, nights are long, and the gnomon shadow line is curved. This can be explained if the tilt angle inclines the north pole away from the sun.

Interpretations

6. Are the rays of light from the light source still perpendicular to the axis of the globe?

Procedures (continued)

E. Measure the height (H) of the gnomon used in making the shadow line for this investigation. Mark off this distance along a vertical line in your notebook. See Figure D.7. Measure the distance from the base of the gnomon to the closest point on the shadow line. Mark this distance along a horizontal line. Complete the triangle. Use your protractor to measure the angle at the top of the gnomon.

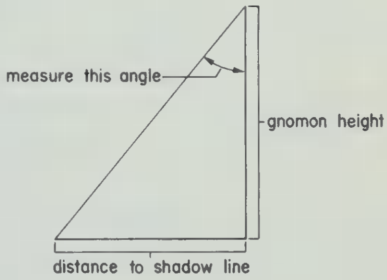


Figure D.7.
Sample drawing for Procedure E.

Interpretations

7. What is the measure of the angle at the top of the gnomon? This angle results from a combination of two things--your latitude and the tilt of the earth's axis (Figure D.8).

8. What is your latitude? (Hint: Look at your notes for Investigation 4.1.)

9. What is the difference between latitude and gnomon angle? (Subtract answer to Interpretation 8 from answer to Interpretation 7.)

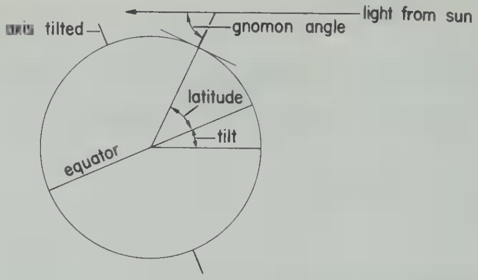


Figure D.8. Gnomon angle equals latitude plus tilt angle.

<u>Procedures</u> (continued)

F. This last angle equals the amount of tilt of the Earth's axis. Use your globe to review the changes in noontime shadow length as the Earth moves from equinox to solstice.

TEACHER MATERIAL

OBSERVATION D.4: The Sun Stands Still (December - January)

Although the investigation should ideally be performed on December 22, that will not always be practical. December 22, the winter solstice, usually occurs during school holidays. And weather is not always suitable for making observations of this sort.

A week of leeway on one side or the other will not markedly affect results. In fact, if the first investigation was performed (say) a week before the September equinox, then this one ought to be performed the same amount of time prior to the solstice.

Materials

If possible teams should use the same gnomons as in preceeding investigations. At any rate the students should be sure to measure the height (H) of the gnomon and record it. In making the records it is not necessary to carry out observations through the entire day. Nor is it necessary to find true north, magnetic north, or determine longitude. All they need to know is the height of the gnomon and the length of the gnomon's shadow at noon.

If it is possible to make observations throughout the day and draw in the shadow line, there should be striking differences between shape of shadow line now and in September. (See Figures T-2.20, T-2.21 and T-2.22.)

Procedures

A. No comment.

B. As mentioned later in the student material, this type of tilting does not represent what actually happens. The Earth's axis remains at the same tilt relative to the plane of the orbit. As the Earth moves around the sun, the direction of the tilt relative to the sun changes.

Interpretations

1. No, an observer's latitude remains fixed.

2. Yes, the gnomon angle will change. If the latitude remains fixed but the gnomon angle changes, the change must result from change in orientation of the tilt.

3. As the pole tilts away from the sun the angle at the top of the gnomon will increase.

<u>Procedures</u> (continued)

C. The light rays are perpendicular to the axis when the globe is in the September position. If students need help deciding whether the light rays are perpendicular, you might suggest that they use the corner of a file card to measure the angle. They could hold one corner of the card at the north pole of the globe and point one of the edges forming the corner toward the light source. If the other edge forming the corner can be pointed in the same direction as the direction of the globe's axis, the rays are perpendicular.

This discussion is really a review of Section Three. It is assumed that students may be a bit rusty on that material by now.

Interpretations

4. No, such conditions cannot be met when light rays are not perpendicular to the Earth's axis.

5. Yes, the sun's rays are perpendicular to the Earth's axis twice a year. In fact the model developed during Section Three and now being reviewed requires that at times, the sun's rays are perpendicular to the axis. See Figure D.6 September position.

Procedures (continued)

D. No comment.

Interpretations

6. No, the sun's rays are no longer perpendicular to the axis of the globe.

Procedures (continued)

E. In Procedures A and B students analyzed sample data. In this procedure students are asked to analyze data gathered using a similar method.

Interpretations

7. Student answers will vary.

8. Student answers will vary. You can either allow each student to use the value he found in earlier investigations, or you can use a standard value for all members of the class. If at all possible use an average value rather than a value taken from an atlas.

9. The accepted value for this angle is 23½ degrees. Again, it would be much better for students to have a slightly erroneous value (such as 19 degrees) and a knowledge of how the value was obtained than to leave class with the "right" number and no idea of how it was obtained.

Procedures (continued)

F. No comment.

OBSERVATION D.5: Locating M31, An Unusual Object

Charles Messier was a French astronomer who lived during the 18th Century. He described and catalogued more than one hundred hazy sources of light in the sky.

Messier 31 (abbreviated M31) is an interesting object that can be seen with the unaided eye. It is located near the constellation of Andromeda.

Procedures

A. In Observation D.3 you learned how to locate the Great Square of Pegasus during November and December. Review those procedures.

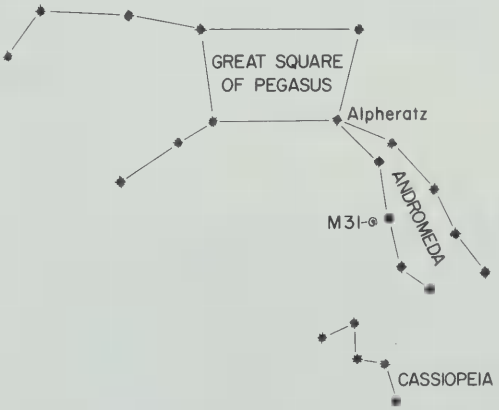


Figure D.9.

B. The two lines of stars extending toward Cassiopeia from the brightest star in the Great Square belong to the Constellation Andromeda (see Figure D.9). The star at which these lines meet is Alpheratz. Locate M31 in Figure D.9 and then try to find it in

the sky. It is not very bright and can be seen only under good viewing conditions. Describe the appearance of M31.

Interpretations

1. What do you think is the nature of M31?

TEACHER MATERIAL

OBSERVATION D.5: Locating M31, An Unusual Object

Procedures

A. The Great Square of Pegasus can be found easily in November and December; but the constellation can also be seen during the late summer or autumn in the eastern and southeastern sky.

B. A line from Polaris through the western side of Cassiopeia leads to Alpheratz in Andromeda.

Students should try looking at M31 through binoculars or a telescope if available. It looks like a bright nucleus surrounded by a haze. To the unaided eye it looks like a "blur" or "smear" of light.

Interpretations

1. M31 is also known as the Andromeda Galaxy, which is pictured in the text in Figure 12.26. This name is avoided in the student text in order to allow students who

1. M31 is also known as the Andromeda Galaxy, which is pictured in the text in Figure 12. . This name is avoided in the student text in order to allow students who are able to locate and observe the object to speculate on its nature. M31 is the only object visible to the unaided eye (in the Northern Hemisphere) which is not a part of our own Milky Way Galaxy.

OBSERVATION D.6: Locating Orion the Hunter
(December to April)

Procedures

A. During the winter months, the constellation Orion the Hunter can be located at 9:00 p.m. by looking in the direction indicated in Figure D.10.

December	January	February	March	April
East	Southeast	South	Southwest	West

Figure D-10.

For example, suppose you select January for locating Orion. Face southeast. Look up about half-way above the horizon, and find three bright stars in a row, fairly close together. These three stars mark Orion's belt. You might also be able to see three fainter stars in Orion's sword.

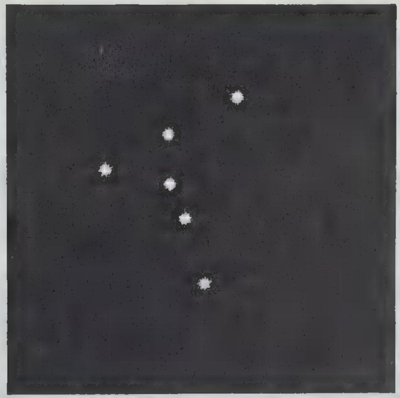


Figure D-11.

Orion's Belt and Sword.

Four bright stars above and below the belt form a rectangle that outlines Orion's body. They are named in Figure D.12.

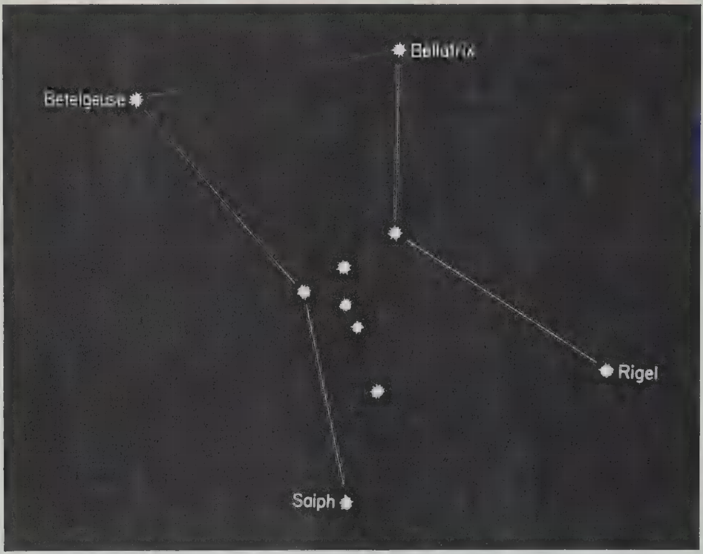


Figure D-12.

Orion's Body.

Figure D.13 shows the way the ancient Greeks may have imagined Orion the Hunter.

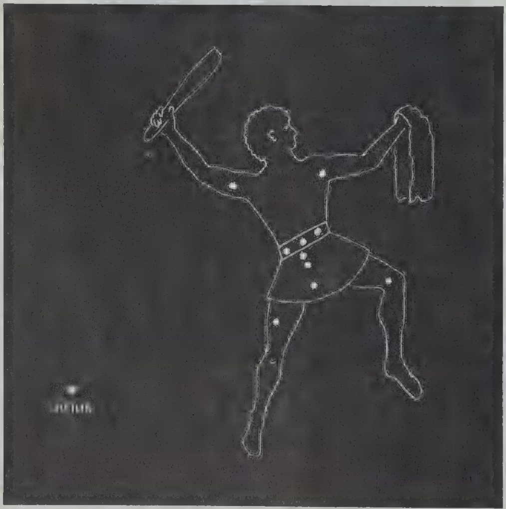


Figure D-13.

Orion
the Hunter.

Sirius, the Dog Star, is seen near Orion's right foot. It is part of the constellation Canis Major and is the brightest star in the night sky.

Interpretations

1. Describe the middle star in Orion's sword.

2. What is the color of Betelgeuse, and what does this indicate about the star's temperature?

3. Describe Rigel.

Procedures (continued)

B. Betelgeuse and Sirius belong to two different constellations. However, these two stars and Procyon, in Canis Minor, make an interesting triangle in the winter sky (Figure D.14). Compare the colors of these three stars. List them in order of increasing temperature (hottest last).

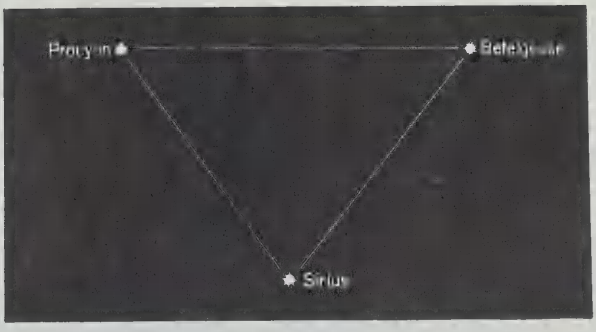


Figure D-14.

The Winter Triangle.

TEACHER
MATERIAL

OBSERVATION D.6: Locating Orion the Hunter
(December to April)

Procedures

A. Orion the Hunter is the most prominent of the winter constellations. Once correctly identified, it is easy to spot. Two very bright stars, Betelgeuse and Rigel, are in this constellation.

Interpretations

1. The middle star in Orion's sword appears fuzzy. It is Orion's Nebula and appears cloud-like in telescopes and in photographs.

2. Betelgeuse is reddish in color. It is relatively cool and extremely large.

3. Rigel is bluish-white. It is a very hot star and the brightest in the constellation. Betelgeuse is second brightest.

Procedures (continued)

B. Procyon, the brightest star in Canis Minor, is a yellow star. Sirius is blue-white and Betelgeuse is red. Listed in order of increasing temperature, they would be Betelgeuse, Procyon, and Sirius.

OBSERVATION D.7: Photographing Star Trails

You have seen that the positions of constellations are predictable. The paths stars seem to follow are caused by the motions of the earth, moving along its orbit through the year and spinning on its axis.

If you have a camera you can make a record of the paths stars appear to follow. If you are not able to take photographs, you can get the information you need to answer the Interpretations in this investigation by looking at Figures D.15 and D.16. Analysis of the paths can be related to the models developed in Sections Two and Three. And it may help you understand the basis for some of the ideas concerning the arrangement of stars in space.

Materials

Camera with time-exposure setting
Tripod

Procedures

A. Plan to photograph the stars on a night that is clear and moonless. (The moon would provide too much light.) Film is rated according to its sensitivity to light. The larger the ASA number, the smaller the amount of light needed to produce a picture. Use film with an ASA rating of 100 or more, if possible.

If a tripod is available, attach your camera to it. This will keep it in a steady position. Otherwise, you will have to prop the camera in a position where it will not be moved.

Many cameras have f-stop settings. If yours does, set it to the widest opening. If your camera has an adjustable focus, set it at infinity.

B. Aim your camera so that Polaris is in the center of your camera's viewer. Set the time exposure and open the shutter. Keep the shutter open for at least an hour. Be sure that nothing will interfere with the camera and that no other object will obstruct the view during this time.

Interpretations

1. If you are successful, your picture will be somewhat similar to the one in Figure D.15.

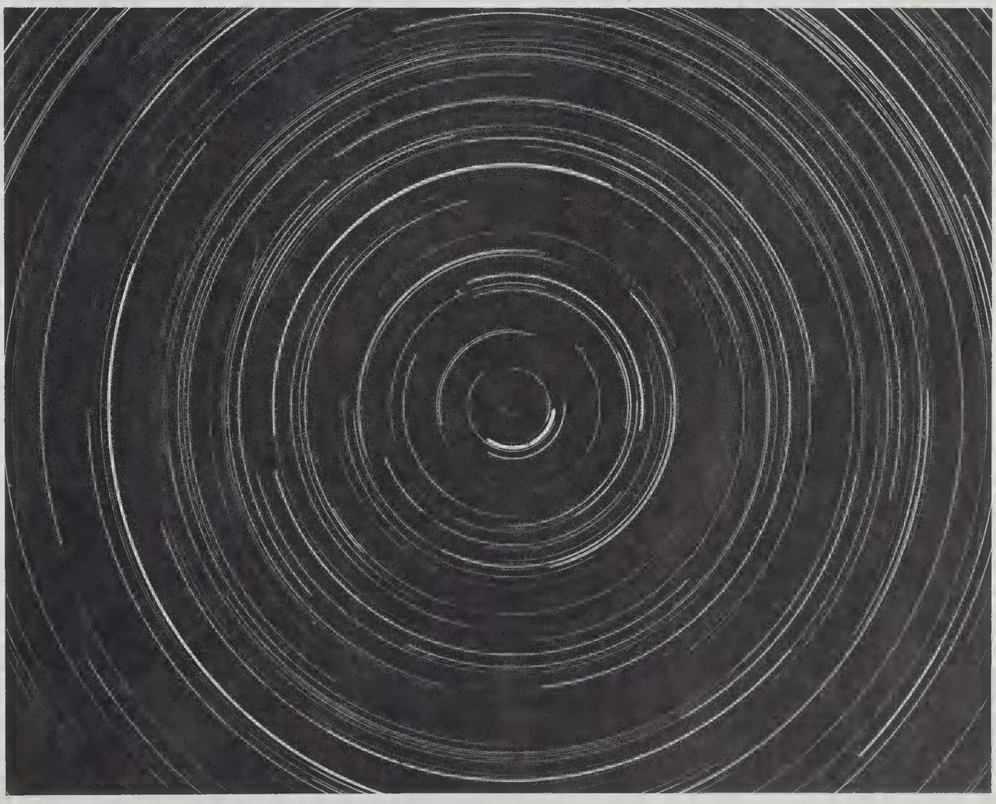


Figure D-15. Star trails near Polaris.

Notice that each arc is only a small portion of a circular path. What part of the circle would each arc represent if the exposure was one hour?

2. Why is it impossible for you to expose the film so that stars trace complete circles?

3. Where and when do you think it would be possible to obtain complete, circular star trails?

<u>Procedures</u> (continued)

C. You can use your camera to take another type of star-trail picture.

Set up your camera as before, but point it at a southern constellation. Sight the constellation so that it appears on the left side of your viewer instead of in the center. This will leave room for the trails to appear.

Open the shutter for only one minute, then cover the lens for five minutes. Uncover it again for about one hour and a half. By covering the lens for five minutes a separation can be made between a picture of the constellation and its trails.

Experiment with several other star trail pictures.

Interpretations

4. Your picture might be similar to Figure D.16. Why are the trail lines straight instead of circular?

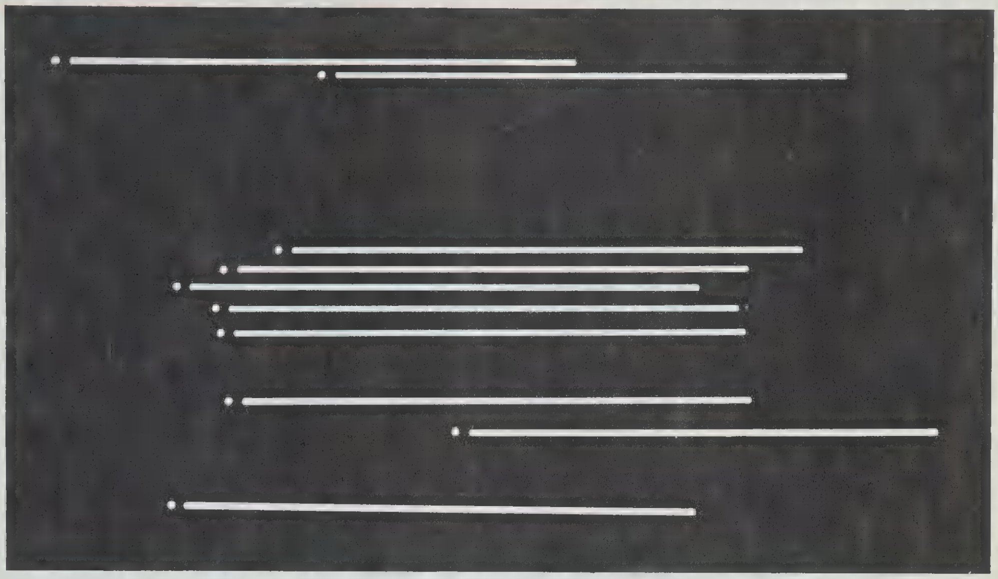


Figure D-16. Star trails.

TEACHER MATERIAL

OBSERVATION D.7: Photographing Star Trails

Materials

Almost any camera will do, but those with f-stop settings will give better results.

Procedures

A.-B. Encourage the students to try this even though they may not have cameras with all of the adjustments mentioned. The key to success is having a stationary camera focused on Polaris for at least an hour.

Interpretations

1. If the exposure was one hour, each arc will be 15° long (1/24 of a complete circle). It is the rotation of the earth that results in the apparent rotation of the circumpolar stars around Polaris.

2. To trace a complete circle of star light would take 24 hours. It would be daylight for part of that time, and stars are not visible during the day.

3. You might be able to obtain complete, circular star trails inside the Arctic Circle after our winter begins, or within the Antarctic Circle during our summer season.

<u>Procedures</u> (continued)

C. Orion can be photographed in winter. Its bright stars will leave excellent trails.

Interpretations

4. The trail lines are not circular because the constellation chosen moves more nearly in a plane with the observer. In Figure D.16 it is shown moving toward the western horizon.

OBSERVATION D.8: Locating the Star Capella (January-February)

Procedures

A. Capella can be found in the night sky anytime from autumn to spring. However, it is quite easy to pick it out between mid-January and the end of February.

To find Capella in mid-January, face north at 9:30 p.m. and look up just about overhead. Capella is the brightest star in this part of the sky.

By January 24 the star will be overhead at 9:00 p.m., at 8:00 p.m. on February 8, and so on until the end of February.

Interpretations

1. Describe the appearance of Capella.

Capella is in the constellation Auriga. It is one of the stars used by sailors and airmen to help them locate their position.

TEACHER
MATERIAL

OBSERVATION D.8: Locating the Star Capella
(January-February)

Procedures

A. Of course Capella can be seen in positions other than overhead. Once it has been identified, it can easily be found in other parts of the spring sky. For example, it can be seen at 9:00 p.m. on March 10 by facing the southwest and looking high in the sky.

Interpretations

1. Capella is the brightest star in the part of the sky viewed. It is yellow and does not twinkle. It is a first-magnitude star and fifth-brightest of all the stars.

OBSERVATION D.9: Locating the Stars Arcturus and Spica
(Mid-March to August)

Procedures

A. Two bright stars can be seen in the vicinity of the Big Dipper during the spring and summer months. To find Arcturus, follow the curve in the handle of the Big Dipper to a bright star (Figure D.17). The distance between the star at the end of the Dipper's handle and Arcturus is about equal to the distance between the Pointer Stars and Polaris.

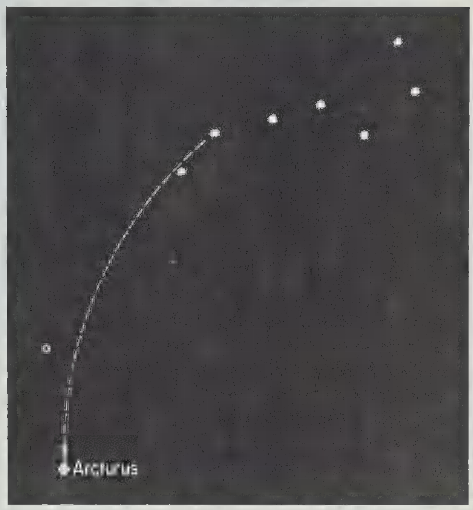


Figure D-17.
Locating Arcturus.

Interpretations

1. What color does Arcturus appear to be?

Arcturus is a star in the constellation Bootes (Figure D.18).

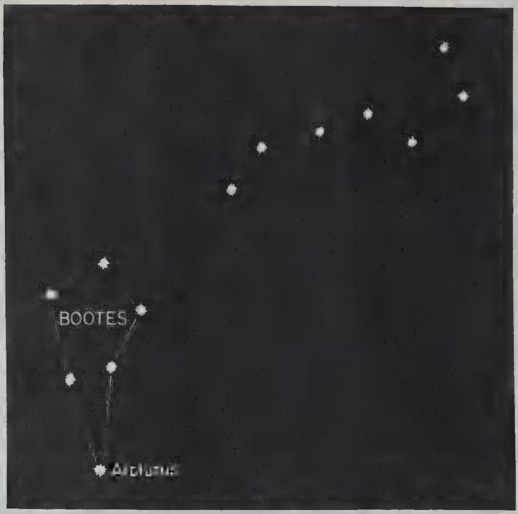


Figure D-18.
The Constellation Bootes.

<u>Procedures</u> (continued)

B. Once you know how to find Arcturus, it is easy to find the star Spica.

Continue tracing the arc from the Big Dipper to Arcturus toward the horizon. The next bright star you will see is Spica (Figure D.19). You can remember how to find the two new stars by the sentence, "Arc to Arcturus and speed to Spica."

Interpretations

2. Describe the appearance of Spica.

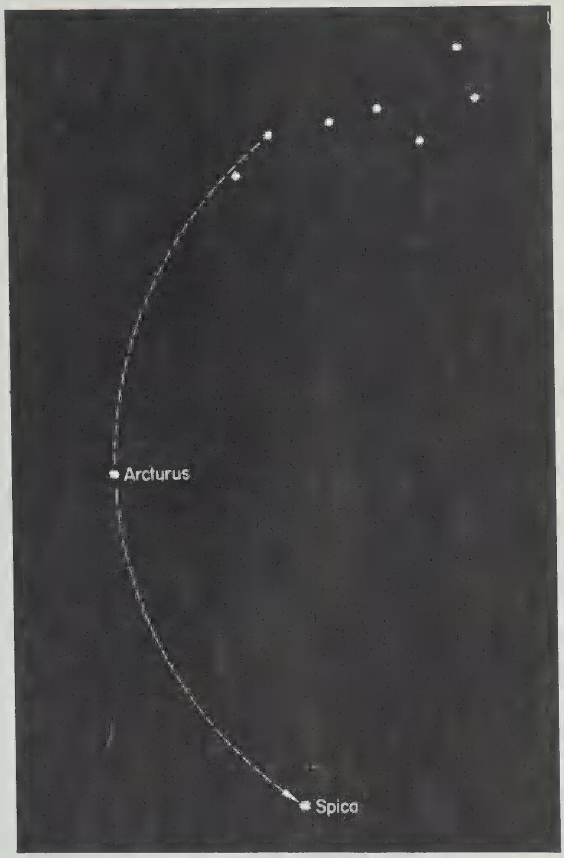


Figure D-19. Locating Spica.

TEACHER MATERIAL

OBSERVATION D.9: Locating the Stars Arcturus and Spica (Mid-March to August)

Procedures

A. No comment.

Interpretations

1. Arcturus appears orange in color. It is a first-magnitude star. It is sixth brightest in the sky and the fourth brightest that can be seen from North America. The diameter of Arcturus is about 30 times that of the sun.

Procedures (continued)

B. No comment.

Interpretations

2. Spica is a very bright star of first magnitude. Its color is bluish-white.

APPENDIX E

EQUIPMENT AND SUPPLIES

Table 1 includes all equipment and supplies needed for the Investigations and Teacher Demonstrations for the Second Experimental Edition of Interaction of Earth and Time. Quantities listed are for a class of up to 35 students, or ten teams of three or four students each. If your classes are substantially smaller, you may wish to decrease the quantities ordered. Most items listed under "equipment" are nonconsumable and can be used for more than one class. Items listed as supplies are largely consumable, and you may wish to increase the quantities listed if you teach several classes. Many items can be obtained locally or provided by students. Also, you may wish to adjust the number of students per team.

Table 2 lists equipment and supplies by investigation or demonstration as an added convenience to the teacher.

* Items marked with an (*) may be considered optional. The course can be taught without them if necessary.

Table 1. Materials for one class.

Quantity	Equipment	Quantity	Supplies
1	Barometer, aneroid	2 boxes	Paper clips (jumbo size)
10	Baking dish	1 spool	Thread
10	Beakers, 600ml, Pyrex	2 rolls	Masking tape, 1/2 inch
5	Compass, magnetic	1 tube	Glue
10	Compass, drafting	10	Gallon jug, empty
5	Burners, Bunsen or equivalent	2	Rubber suction darts
20	Rulers (Metric-English), flexible plastic (30cm)	2 pkgs.	3 x 5 file cards
1	Magnet, horseshoe shaped (small)	2	Marking pen
1	Light source, slide projector*	1 ream	Paper, 8 1/2" x 11", white
10	Light source, lamp	8 feet	1 x 12 pine or fir
5	Pliers, needle nose or tongs	2	6 penny nail
1	Clock (second hand)*	10	Wire clothes hanger
35	Protractor	5 pkgs.	Modeling clay
10	Scissors	1 box	Straight pins
10	Globe (small, Nerf ball or equivalent)	1 box	Rubber bands
1	Globe (large, unmarked)	35	Cardboard, 20cm x 20cm
1	Stapler	35	Weight, fishing, 1 oz.
10	Meter stick	1 ball	String, kite type
5	Ringstand with rings, clamps & wire gauze		Ice
5	Triangular file	1 bottle	Food coloring (vegetable dye)
10	Weight (force) gauge (see text)	15	Solid metal objects
1	Hydrometer	1 pt.	Ether*
10	Erlenmeyer flasks, 250ml		Yeast*
			Drosophila culture*
		10	Tin cans, large (#10)
		1 roll	Aluminum foil, heavy
		1 g	Indicator solution (bromthymol blue)
		10	Baby food jars, without lids

Quantity	Equipment
10	Stoppers, one-hole #1
10	Stoppers, two-hole #6
10	Graduated cylinders, 100ml
20	Thermometer, alcohol, -10°-110°C
1 each	Cylinders, oxygen, nitrogen*
1	"Superball"
9	Concrete building blocks, approx. 7 1/2" x 7 1/2"
1	Balance, 0.01g sensitivity*
1	Wire cutting pliers
5	Floodlight
1	Hammer
1	Knife
50	Magnets, ceramic
1-5	Light meter*
10	Lens, 1 1/2" diameter focal length 1"
10	Lens, 1 1/2" diameter focal length 12"
10	Lens, 1 1/2" diameter concave*
10	Diffraction grating, transmission type (3cm x 3cm)
	Light sources
1	Neon bulb
1	Fluorescent bulb*
6	Incandescent bulbs, assorted wattages (200, 100, 75, 60, 50)
10	Mirror, concave, shaving
10	Mirror, flat, small

Quantity	Supplies
10	Baby food jars, with lids
2 pkgs.	Drinking straws
1 pt.	Mineral oil
1 pkg.	Plastic bags, 1 qt. size
10	Candles
1 box	Matches, safety
1 pt.	Dilute hydrochloric acid
20 ft.	Rubber tubing (to fit 6mm O.D. glass tubing)
2 lbs.	Glass tubing, 6mm O.D.
2 lbs.	Lead shot #4
20	Test tubes, 18 x 150mm
10	Wire screen 1/2" mesh 8" x 8"
1 pad	Graph paper, 1/2" grid
1 box	Toothpicks
1 pkg.	Paper plates, small
1 pkg.	Plaster of Paris
1 bottle	Petroleum jelly
1 box	Slides, microscope
1 roll	Plastic wrap
1 roll	Transparent tape
50	Wood blocks, approx. 1x9x9cm
1 pkg.	Black construction paper
1	Ditto fluid can, empty
1 pkg.	File cards 5" x 6"
1 lb.	Table salt
6"x6"	Cloth, cotton
10	Sponge
1	Bucket, 3 gallon
5 lbs.	Sand

Quantity	Equipment	Quantity	Supplies
		1 lb.	Feldspar
		1 lb.	Calcite
		1 lb.	Mica
		1 lb.	Quartz
		10	Medicine droppers
		1 oz.	Salol
		10	Lodestone
		10	Sedimentary rock set
		10	Mineral set
		10	Stirring rod
		1 pkg.	Paper cups
		1 pkg.	Cornstarch
		1 ream	Quadrille paper
		20	Cardboard, 25cm x 25cm
		10	Small, flat-sided bottles with cap
		1 pkg.	Non-fat dry milk
		10	Metamorphic rock set
		10	Igneous rock set
			Gauze
			Drosophila medium
		5	Shoebox
		1	Container, plastic 4" x 4"
		1	Bottle, detergent
		10	Dice

Table 2. Materials per team per Investigation.

Note: Items from the general list in Table 1 are arranged by Investigation (or Inquiry Demonstration) and in quantities for one team, except as noted.

*Activities marked with an asterisk require only one set-up as they are teacher demonstrations.

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
1.1			Ruler (Metric-English) Lodestone (rock) Ceramic magnet	Paper clips Thread Masking tape (1/2" wide)
*Inquiry Demonstration Magnets & Models (Optional)		Horseshoe-shaped magnet	Needle nosed pliers Bunsen burner	Paper clip Glue
1.2		Compass (magnetic)	Ruler (Metric-English) Protractor	
*Inquiry Demonstration Day & Night		Globe (large-unmarked)	Light source (slide projector is best)	600ml beaker or wide-mouth jar Rubber suction darts (2) 3 x 5 file cards (2) Masking tape Marking pen
2.1		Compass (magnetic) Watch or clock	Ruler (Metric-English)	Paper, unruled 8 1/2 x 11 Masking tape Paper clip (large) 6 penny nail (or electric drill)
2.2		Compass (drafting)	Protractor Ruler (Metric-English)	Gnomon record from Inv. 2.1.

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
2.3		Globe (small) with axis and base, "Nerf" ball or equivalent	Scissors Light source (see TM on types of light source)	Wire clothes hanger Modeling clay Record of outdoor gnomon Straight pins (3) 3 x 5 file card
2.4		Globe (small) same as for Inv. 2.3	Light source (same as Inv. 2.3) Protractor	Rubber bands (5) Straight pins (3)
2.5		Globe with axis and base (same as for Inv. 2.3 & 2.4)	Light source (same as for Inv. 2.4) Protractor	3 x 5 file card Outdoor gnomon record Straight pins (3)
2.6		Compass (magnetic) Optional--See Inv.		
*Inquiry Demonstration Models of Tilting (TM only)		Globe with axis and base	Light source	Wire coat hanger for annular ring
3.1		Globe (as used in Inv. 2.4)		Straight pin Masking tape
3.2		Globe with axis and base (same as in Inv. 2.4)		Straight pin Blank paper
4.1			Protractor Scissors Ruler (Metric-English) Stapler	Cardboard, 20cm x 30cm Weight, fishing type String

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
4.2		Compass (drafting)	Protractor Watch or clock Ruler (Metric-English)	Gnomon board & gnomon
5.1			Ruler (Metric-English)	
5.2		Meter stick or 30cm ruler		
5.3		Meter stick	Ruler (Metric-English) Protractor	3 x 5 file cards Masking tape Unruled paper
Optional Student Investigation (in TM)		Meter stick	Protractor	Astrolabe (See Inv. 4.1) Masking tape
*Inquiry Demonstration		Ringstand Ringstand clamps (2) Triangular file	Erlenmeyer flask, 250ml One-hole stoppers (2) Glass tubing, 6mm O.D. Bunsen burner	Food coloring (vegetable dye)
5.4			Graduated cylinder, 100ml	Solid objects (3) (different weights and sizes) Masking tape
5.5		Weight (force) gauge (see Inv. 5.5 TM)	Graduated cylinder, 100ml	Same solid objects used in Inv. 5.4

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
6.1			One-hole stopper #1 (2) Scissors Ruler (Metric-English) Graduated cylinder, 100ml	Test tube, 18 x 150mm 3 x 5 file card Candle Matches Glass tubing, 6mm O.D. (11cm long) Lead shot #4 Salt
6.2			Hydrometer (student made) Graduated cylinder, 100ml Beaker, 600ml	Salt solution, 4% Stirring rod
6.3		Thermometer Ringstand, ring and wire gauze	Hydrometer (student made) Graduated cylinder, 100ml Heat source	"Sea" water (artificial) (see TM for preparation) Ice Matches Tin can, 7" high
6.4		Thermometer Ringstand, ring and wire gauze	Hydrometer (student made) Graduated cylinder, 100ml Heat source	Tin cans, large (2) "Sea" water (see TM) Aluminum foil, heavy
6.5 *Optional items for teacher demonstration only (see TM)		Cylinders: oxygen, nitrogen and carbon dioxide (optional) (baking soda can be substituted for CO_2 cylinder)	Graduated cylinder, 100ml Erlenmeyer flask, 250ml (optional)	Indicator solution (see TM) Jar without lid Jar with lid Drinking straws Mineral oil (optional) Plastic bags, 1 qt. (optional) Rubber tubing (optional) Dilute hydrochloric acid (optional)

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
*Optional Demonstration			Erlenmeyer flasks, 250ml (2) Two-hole stoppers for flasks (2) Hot plate or burner Thermometer	Indicator solution (bromthymol blue) Glass tubing, 6mm O.D.
Optional Investigation (see TM)				String Weights Thread Vials or test tubes Gallon cans Masking tape Paper clips
6.5			Ruler (Metric-English)	One gallon cans Powdered milk Lead weight, 1 oz. String Wire screen, 1/2" mesh, 8" x 8" Graph paper, 1/2" grid Masking tape Paper clips Toothpick Glass tubing, 6mm O.D.
*Inquiry Demonstration Bouncing-ball "sonar"		Concrete building blocks, 7½" x 7½" (approx.), 9 ea. "Superball", 1 1/2" diameter		Large cardboard carton Butcher paper (optional-see TM)

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
7.1		Watch or clock w/ sweep second hand	Ruler (Metric-English) Meter stick (1 per class)	
*Inquiry Demonstration Interpretation of Preserved Evidence				Paper dishes Assorted objects "Fibre-Clay" or Plaster of Paris
*Optional Demonstration		Lens, 1" focal length		Gauze Large, wide-mouth jar Tape Ether Yeast Drosophila medium
8.1		Thermometer		
Optional Investigation		Glass plate, 2" x 6" or Microscope slides 1" x 3" (4) Balance, sensitive to .01g (1 per class)		Masking tape Petroleum jelly

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
8.2			Scissors	Aluminum foil Cardboard tubes (2) Masking tape Matches Paper towels Plastic wrap Transparent tape Black construction paper Shoe box (5) Candle
Inquiry Demonstration		Aneroid barometer	One-hole stopper	Bucket Can, ditto fluid, empty File card Tubing, rubber String Tubing, glass 6mm O.D. Drinking glass
8.3		Thermometers (2)	Beakers (2) Flood light Ringstand Ringstand ring	Soil or sand
8.4		Magnetic compass	Scissors Wire cutter	Coat hanger, wire File cards 5" x 6" Paper clips Thread Masking tape

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
8.5			Beakers (2) Bunsen burner Ringstand and ring One-hole stopper	Ice Salt
8.6		Thermometer		Stirring rod Ice Tin can Towel
8.7		Thermometer		Cloth, cotton File card Rubber band
8.8				Matches Jug, gallon
8.9				Quadrille paper
9.1		Baking dish Sponge		Sand Bucket (1 per class)
9.2		Baking dish	Hammer (1 per class) Knife or razor blade (1 per class)	Calcite Feldspar Mica Quartz Detergent Soda straws

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
9.4		Magnifying lens	Hot plate Watch glass (2)	Masking tape Dropper (1 per class) Salol Stirring rod
9.5		Volcanic rock set Mineral set		
9.6		Clear glass bottle with lid	Ruler (Metric-English)	Sand
9.7		Sedimentary rock set Mineral set Magnifying lens	Ruler (Metric-English)	Acid, dilute, in dropper bottle (1 per class)
9.8		Die		Quadrille paper
9.10		Igneous rock set Mineral set Magnifying lens		Acid, dilute, in dropper bottle (1 per class)
9.11		Metamorphic rock set Mineral set Magnifying lens		
9.12			Beaker Ruler (Metric-English) Test tube	Marking pencil Ice Table salt
10.1			Scissors	Thin, unruled paper
10.2		Baking pan	Ruler (Metric-English)	Wood blocks

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
10.3		Ceramic magnets (5)	Scissors Wire cutter (1 per class)	Wire coat hanger Rubber bands Paper clips Masking tape
10.4		Ceramic magnet (1) Magnetic compass	Hammer	Paper cup Masking tape Patching plaster Plastic container, 4" x 4"
10.5			Protractor Ruler (Metric-English)	Quadrille paper
10.6			Container Spoon or nail	Cornstarch
11.1		Light meter Light source	Ruler (Metric-English) Protractor	Masking tape
11.2			Beakers (2) Ruler (Metric-English)	Paper cup Masking tape
11.3				Paper
12.1		Light meter	Lamp Meter stick	200-watt bulb
12.2		Light meter	Lamp Meter stick	200-watt bulb 100-watt bulb 75-watt bulb 60-watt bulb 50-watt bulb

INVESTIGATION	PAGE	SPECIAL EQUIPMENT	STANDARD EQUIPMENT	SUPPLIES
12.3 (optional)			Meter stick Scissors	Cardboard, 25cm x 25cm Masking tape Paper clip
12.4			Tongs or pliers Bunsen burner or propane torch	Paper clip
12.5		Lenses, 1 1/2" diameter (2) a. focal length-1" b. focal length-12"	Ruler or other straight edge	Small flat-sided bottle, with cap Pitcher Coin Flat-bottomed cup (opaque)
12.6		Lenses (same as for Inv. 12.5)	Ruler (Metric-English) Scissors	Masking tape Construction paper (2 sheets)
12.7		Lenses (same as for Inv. 12.5) Concave shaving or make-up mirror Small flat mirror	Light source	Modeling clay
12.8		Transmission type diffraction grating (3cm x 3cm)	Bunsen burner or propane torch Neon bulb Fluorescent bulb Standard bulb Ruler (Metric-English) Scissors	Masking tape Paper clips Construction paper (dark) Table salt
*Inquiry Demonstration		Knife	Meter stick	Kite string, 1 ball Towel tubes (9)

Date Due